ASSESSMENT OF SOIL FERTILITY AND FARMERS MANAGEMENT PRACTICES UNDER RAIN FED AGRICULTURE IN GWAGWALADA AREA COUNCIL, FEDERAL CAPITAL TERRITORY, NIGERIA

BY

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DECLARATION

I declare that the work in the thesis entitled "assessment of soil fertility and farmers' management practices under rain fed agriculture in Gwagwalada Area Council, Federal Capital Territory, Nigeria" has been performed by me in the Department of Geography under the supervision of Professor Jayeoba I.A. and Professor Iguisi E.O. The information derived from the literature has been duly acknowledged in the text and the list of references provided. No part of this thesis was previously presented for another degree or diploma at any university.

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Signature

09/05/11

Date

CERTIFICATION

This thesis entitled ASSESSMENT OF SOIL FERTILITY AND FARMERS MANAGEMENT PRACTICES UNDER RAIN FED AGRICULTURE IN GWAGWALADA AREA COUNCIL, FEDERAL CAPITAL TERRITORY, NIGERIA by Madaki, Yusuf Haruna meets the regulations governing the award of the degree of M.Sc. Geography of Ahmadu Bello university, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicate this work to all the peasant farmers in Nigeria and Africa as whole.

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ABSTRACT

Gwagwalada is one of the area council of the FCT with one of its defined functions by its master plan of supplying to the capital city, food and some agricultural raw materials. This, studies is made to ascertain the soil fertility status and the farmer's management practices in the area council. The aim is to assess the soil fertility status and the farmer's management practices under rain-fed agriculture. Seven farming communities of Giri-Wuna, Giyabiri, Ledi, Dadabiri, Paikon Kore, Tungan Mallam Hassan and Gurfata were selected. From each farming community four bulked samples was taken on farm plots and were analysed for key soil fertility properties using standard laboratory procedures. SPSS 2008 version was used to analyse the data generated from the laboratory analysis to test for significant difference amongst the locations using ANOVA and between pairs of locations using t-test. The farmer's management practices were assessed using structured questionnaire and personal interview with the farmers in various farming communities. The soil fertility status was rated based on the rating scale adapted from soil survey staff (USDA) of 1975. The result of ANOVA shows no significant difference for most of the soil properties except for silt, bulk density, Exch. Mg, Exch. Acidity, pH and SAR. Most of the pairs of locations also show no significant difference. The results of soil ratings show that most of the soil properties tested are within satisfactory range for annual cropping of cereals and tubers for which the study area is known for. The soil management survey reveals that most of the active farmers are above 36 years of age who have not acquired any form of formal training and own more than three farm plots of not less than 8 hectares. The major crops grown in the area are yams, guinea corn and maize. The major degradation reported and assessed in the area is weak aggregation of soils. The basic systems of farming in the area are mixed cropping in Giri-Wuna, Giyabiri,

Ledi, Dadabiri and Paikon Kore and mixed farming in Tungan Mallam Hassan. Bush fallowing and crop rotation are important soil conservation methods in the area but farmers also use manure and chemical fertilizers to improve their soil fertility.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

The fertility of soil is its capacity to support the climax population of plants and animals above ground, and the associated flora and fauna below ground. When taken over for agriculture the soil fertility becomes its capacity to produce the crops desired, (Cook, 1967). A fertile soil is that which can support abundant plant life through the supply of available nutrients, under favourable bio-physical and physio-chemical conditions. A fertile soil should be rich in nutrients for basic plant nutrition; the primary nutrients for plant growth are nitrogen, phosphorus and potassium (NPK). In addition to these primary nutrients, less intensively used secondary nutrients such as sulphur (S), calcium (Ca) and magnesium (Mg) are necessary as well. A number of micro- nutrients such as chlorine (Cl), iron (Fe), manganese (Mn), zinc (Zc), copper (Cu) and molybdenum (Mu) also influence plant growth (Gruhn *et al,* 2000 and Mashi 2005). The physical, chemical and biological characteristics of soil are also important components of soil fertility. Although Jacks (1963) stated that the natural fertility of a soil is biophysical rather than a physio-chemical alone.

Soil nutrient availability involves complex biological and chemical interactions, some of which are not fully understood (Gruhn et al, 2000). These interactions involves inputs of mineral fertilizer, organic manures, atmospheric deposition, biological nitrogen-fixation and sediments to plants, for output such as harvested crop parts, crop residues, leaching, gaseous losses and water erosion.

The differences between the volume of inputs and outputs are term the nutrient balance. Gruhn et al, (2000), describes the balance to be of positive and negative types. The positive balance occurs when nutrient additions to the soil are greater than nutrient removal from the soil and this indicates that the farming systems are insufficient and in the extreme may be polluting the environment. Negative balance on the other hand indicates that soils are being mined and that farming systems are unsustainable over the long term.

A condition of decline of soil quality and therefore its current and potential productivity and/or reduction in its ability to be a multipurpose resource is described as soil degradation (Lal et al., 1978). Soil degradation entails an unfavourable alteration in one or all of a soil properties and processes. According to Young (1979) a degraded soil is not simply one that is poor, soils which are naturally highly fertile can and have been degraded. Conversely, soil of low inherent fertility which is still in their natural state, cannot be describe as degraded.

There is growing concern over long-term sustainability of agriculture world over. Both over and under application of fertilizers, and poor management of resources, has led to soil degradation (Gruhn et al, 2000). In developed countries for instance, over application of inorganic and organic fertilizers has led to contamination of water supply and soils (Boub and Banante, 1996). In developing countries on the other hand, harsh climate conditions, population pressure, land constraints and decline of traditional soil management practices has often reduces soil fertility (Hanoa and Banante, 1999). According to FAO report, agriculture in sub-Saharan Africa over the period of 1961-1992, failed to increase the production of food calories per capital

above 2100/day (Alexandratos, 1995). Projecting to 2010, Mortimore and Haris (2005), argued that the region could not generate growth on the scale necessary to both feed its growing population and catch up with a predicted developing average of 2730/day, a scenario directly linked to soil degradation in the face of growing population (White and Killick, 2001).

Soil fertility decline is generally spread in the tropics and this is largely associated with annual cropping, subsistence farming with poor management practices. The effects of decline soil fertility on yield growth are particularly visible in Africa were there is serious food challenges (Badiane and Delgado, 1995). The low level of chemical fertilizer use, decline in soil organic matter, and insufficient attention to crop nutrient studies contribute the most to the loss of soil fertility in the region (Kumwanda et al, 1996).

In the arid, semi-arid and sudano-sahelian area that are densely populated for example, soil loses 60-100 Kg of NPK per hectare every year. In the sub-humid and humid regions of savannas and forest areas, nutrient losses vary greatly (30 to 60 Kg of NPK per hectare per year (Mashi, 2005).The effects of these, results in negative nutrient balance other wise term soil mining (Gruhn et. al., 2000; Mortimore and Harris, 2005 and Mashi, 2005)

In Nigeria, some researches have been carried out on soil degradation and resilience, and soil management practices in the Northeast, Northwest, Southeast and Southwest. Such researches on soils are however very few in the north central of Nigeria.

1.2 STATEMENT OF THE RESEARCH PROBLEM

The key to sustainable economic development that depends on agriculture in Africa are the development, use and management of essential agricultural resources and successful restoration of the vast degraded landscapes in the countries. Despite the recognition of the problem of land degradation and its impact on agricultural productivity at aggregate national scale in Nigeria, few scientific studies have been conducted at a small spatial scale, such as the farm level, to provide quantitative information on the status of soil fertility (Malugeta, 2000), especially in the north central.

Gwagwalada Area Council is one of the six-area council of the FCT, with one of its defined functions by its master plan of supplying to the capital city food and some agricultural raw materials. Gwagwalada Area Council lies within agricultural zone with vast of the land heavily cultivated, to meet up with the increasing demands for food and to sustain environmental integrity in the FCT, soil quality must be enhanced and maintained. Therefore, studies are needed to ascertain the soil fertility status and the farmer's management practices in the territory.

1.3 Aim and Objectives

The aim of this study is to assess the soil fertility status and the farmer's management practices under rain-fed agriculture in Gwagwalada Area Council of the Federal Capital Territory.

The specific objectives are to:

i. determine and compare key fertility properties of selected rain-fed arable land and adjacent relatively undisturbed land in the area,

ii. identify and characterize farmer's management practices in the area.

1.4 Justification

Researches have shown that the major problems of agriculture in sub-Saharan Africa is soil degradation which is promoted by increasing pressure on land and intensification of farming with poor management practices (Mortimore and Harris, 2005). This is manifested in crops and land shortage, decreasing farm size, reduced fallow and soil mining (Hoffman et al, 2001). From the first edition of the world atlas of desertification (UNEP, 1990) and surveys carried out by ISRIC (Oldman and Hakkeling, 1990) and Winiran Staring Centre (Stoorvogel and Smalling, 1990), the area affected by soil degradation in arid, semi-arid and dry sub-humid agro-ecological zone alone amount to about 332 million hectares, or 25.8 percent of the surface of Africa. This situation will be on the increase if left unchecked. Hence, knowledge of soil condition of an area would serve as a baseline for decision and policy making to abate over exploitation of the soil nutrient base of an area and adapt appropriate soil quality control measures, in order to enhance environmental conservation and sustainable agricultural productivity. And in order to keep pace with the growing population of the FCT food requirement and environmental conservation, there is a need to have knowledge of the soil quality of the area and the farmer's management practices.

1.5.0 Literature Review

1.5.1 The Concepts of soil quality, degradation and sustainability

Soil quality is the ability of the soil to perform its function in a sustainable manner (Mashi, 2005). This is the capacity of specific soil to function within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality and support human health and habitation (Brady and Weil, 1999). The capacity of soil to be productive depends on more than just plant nutrients. The physical, biological and chemical characteristics of soils are also important components of soil fertility. These components as organic matter contents, acidity, texture, depth and water retention capacity all influence fertility. Because these attributes differ among soils, soils differ in their quality (Lobry de Bruyn and Abbey, 2003). Soil quality reflects biological, chemical and physical properties, processes and their interaction within each resource unit. Lal (2001) pointed out that soil supports terrestrial life through five processes (i) biomass production (ii) restoration and resilience of ecosystem (iii) purification of water (iv) detoxification of pollution and (v) cycling of C, B, P, S and water.

Soil's potential for producing crops are largely determined by the environment they provide for root growth (Gruhn et al, 2000). Root needs air, water, nutrients and adequate space to develop. Soil attributes such as capacity to store water, acidity and depth and bulk density determine how well root develops. Changes in these soil attributes directly affect the health of the plant, for instance, when bulk density of a soil increase to a critical level, it become more difficult for root penetration, these changes in soil quality affects the health and productivity of plants (NRC 1993).

Soil quality is depleted as the soil is degraded through individual or combined

processes of soil degradation. Soil degradation in Nigeria is mainly by soil erosion, compaction and soil mining. When a soil is degraded, its capacity to produce biomass is reduced. Recovery of the soil through efforts to rehabilitate it depends on the inherent capacity of the soil and the level of degradation reached before rehabilitation effort (Salako, 2003).

The soils of the savannah regions of Nigeria are physically fragile because the topsoils contain a large proportion of sand, causing weak aggregation due to the low level of organic matter in this layer. The physical constraints are further compounded in gravely soils or soils with shallow depth overlying plinthic or hardpan layer (Adeoye and Mohammed-Saleen, 1990; Salako et al, 2002). Hence, the soils of this region indicate some level of degradation.

The term 'sustainable soil nutrient' implies that plant nutrients and the soil physical environment suitable for plant growth remain at a steady state for the long-term (Mulugeta, 2004). Doran (2002) suggested that one way to ensure sustainable soil nutrient is to make sure that all nutrient taken up by plant during growth are returned to the soil so that they can be use again by plants of the next production cycle, in this manner, a nutrient cycling is established (King, 1990).

1.5.2 The Concept of Soil Resilience

As soon as land is newly put into production, the soil degradation processes are set in motion triggering deterioration of soil structure and disruption of cycles of carbon, depletion of soil nutrient reserves and weakening of nutrient recycling mechanism (Lal 1974, 1976 and 1994). However, soils have an inherent ability to restore their life support processes, provided that the disturbance created especially by human

activities is not too drastic, and sufficient time is allowed for the life support processes to restore themselves (Lal 1994). This intrinsic soil productivity regeneration ability is called *resilience.*

In a research conducted by Tenywa et al (1999) showed that soil resilience occur at different rates and stages in their comparative analysis of the resilience stage of Miamian Typic Hapludalt at Ohio (USA) and of a sandy clay loan Kandiudult at Makerere (Uganda) using selected soil properties and corn grain Yield, and the result reveals the Miamian soil to have high resilience than that of Makerere.

Mashi and Yaro (2004) observed the role of fallowing in soil renewal under dry Nigerian savannah climate at different fallow lengths. The result reveals higher soil quality with length of the fallow periods of 2, 5, 10 and 15 years.

1.5.3 Soil Degradation

Soil degradation can occur naturally but it is often accelerated when human activities directly or indirectly set in motion, the process, which begins with the loss of vegetal cover (Malugeta, 2004). The causes, processes, result and effects of degradation are illustrated in figure 1.2 in page 9. Of all activities of man that have great impact on soil, cultivation is the most prevalent (Jaiyeoba and Leow, 1983). The Global Assessment of Soil Degradation (GLASOD) study, reported human-induced soil degradation processes resulting in soil erosion by water, wind and soil physical and chemical deterioration (Oldman, 1994). Studies show land uses as being the primary causes of soil degradation.

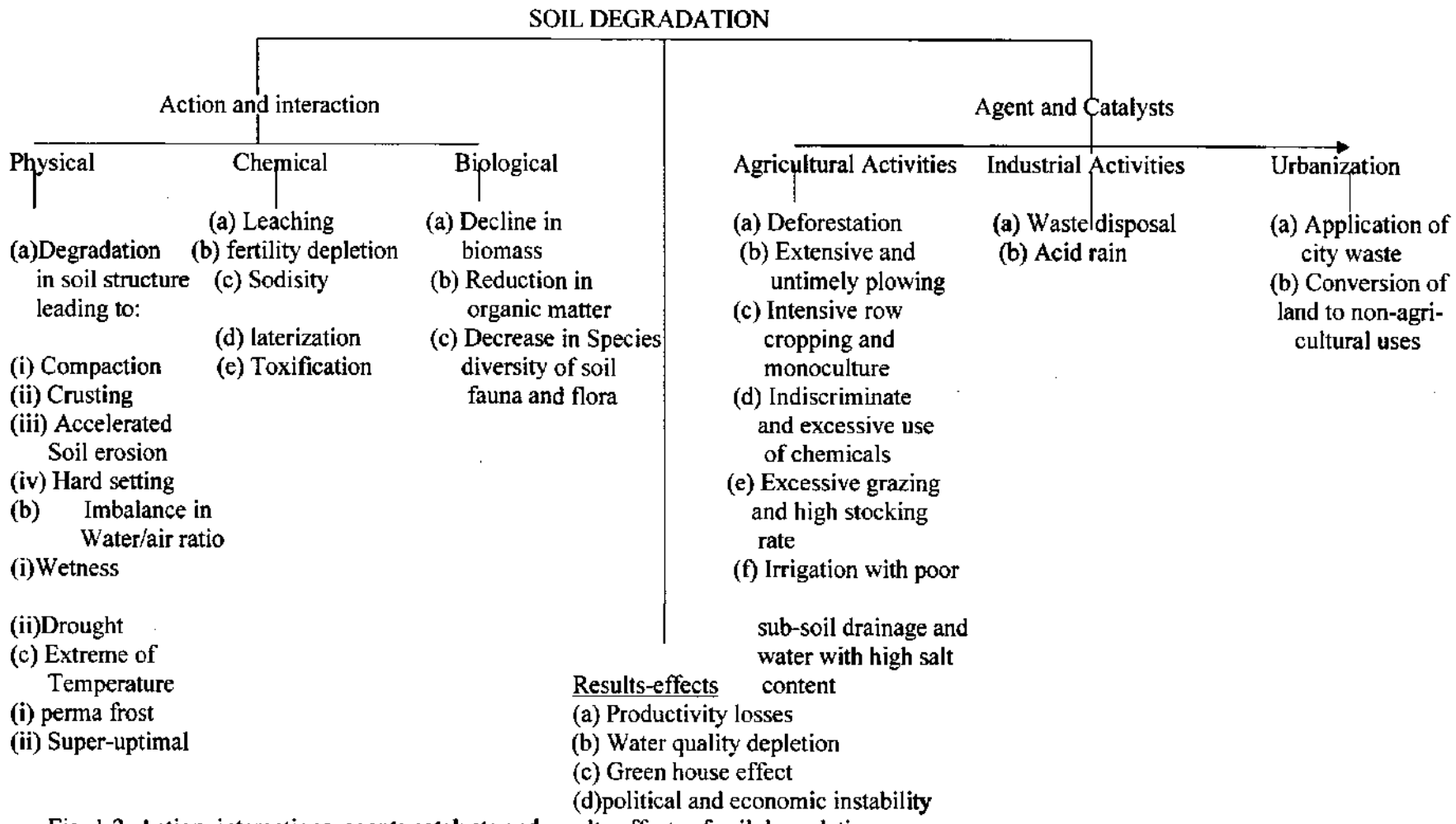


Fig. 1.2 Action, interactions, **agents catalysts and** results-effects of soil degradation
Source: Lal *et al* (1989).

Tillage, for instance, is the physical manipulation of soil; hence, the most profound effect of tillage is in relation to soil physical properties. The physical properties that are altered by tillage are bulk density, water content, penetration, resistance, soil temperature and aggregate stability (Salako 2003). Lal, (1997) demonstrated that tillage plots are more susceptible to soil· erosion as aggregates will be loosens and this results in alteration of soil texture. This is achieved by exposing them to the influence of high kinetic energy of rainfall (Aina, 1979).

Different scholars, who show that different cultivation methods have different effects on the physical properties of soil, carried out extensive studies of tilth and tillage in the northern Nigeria. The studies show that local farmers using their crude implements have less adverse effect on soil physical properties compared to the mechanised system (Wali 1986; Jaiyeoba and Leow, 1983 and Aremu, 1979).

Also, some studies in Northern Nigeria shows that tillage's and exposure of soil to direct insulation and rains tend to increase the rate of day dissolution and removal of top soils (Jaiyeoba and Loew 1983). Soils in the region assumed weak aggregate and weak soil structure under continuous cultivation (Kowal, 1972; Jones and Wild, 1975). Jones (1971) also observed that there is a decrease in carbon content in soil after twenty years of continuous cropping without the use of fertilizers.

In Southern Nigeria, Lal (1997), showed that tillage plots are more susceptible to soil degradation compare to no tillage plots. On an Alfisols in South-Western Nigeria where there is low clay content, silt was more eroded causing increase in sand content of tillage plots compared with no tillage plots as cultivation progresses from 1982 to

1986. Available water content and water infiltration were highest under no tillage and both were particularly low for ridge-tilled plots. Less erosion of particles enhanced water retention in the no tilled plots while the high infiltration rates where due to high macro porosity.

Mulugate (2004) in a comparative study of the effects of traditional low tillage farming (TF) and high intensive mechanized farming (Mf) on different agricultural plots in Ethiopia shows Mf with significantly higher bulk density of 1.07gcm^{-3} compared to 0.85gcm-^{3} under the TF and 0.66gcm-^{3} under the adjacent natural forest between 0-10cm layer. Similarly, the soils under MF exhibited greater total C, N and base cation decrease compared to the soils under TF.

Bouer (1972) noticed in Kenturky (USA) a decrease of 16-18 percent in porosity of cultivation area compared to virgin forest area during forty years of continuous cultivation. It was also observed that there is decrease in organic matter content, cation exchange capacity and soil PH value in Casemence after years of cultivation. In Mediterranean mountain environment in area dominated by Entisols and Inceptisols and soils with hydromorphic feature shows sign of heavy erosion, and all sites show a weak water storing capacity, depletion of organic matter in addition to increase infiltration and runoff under a decade of cultivation (Seeager and Ries, 2008). In Bolivian mountain valley, continuous cultivation of small crop land fields has increased soil degradation and consequently led to less water and nutrient availability (Kessler and Stroosnijder, 2005).

Observing the effect of tillage on accelerating soil degradation, Lal (1979) advocated

management of soils in Southern Nigeria with no tillage on short slopes (less than 100m length) as the rate of increase in bulk density was higher for conventionally tilled plots compare with no tillage. Aina (1979) suggested that soil conservation in tropical areas is more suitable with the use of zero or no tillage and mixed cropping system.

However, tillage can be used to control the structure of soils, because it helps to reduce erosion by producing rough surface, thus, increasing the frictional resistance of the soil to both wind and water, also break soil surface crust thereby increasing porosity, infiltration and decreasing over land flow and also help in weed control (Kassan, 1987). Mound tillage was also found to improve soil bulk density significantly compared to flat tillage in compacted soils ameliorated with planted fallows in Southern Nigeria (Salako et al, 2001). Although drying and increase in soil temperature on ridge and mounds occurs if they are not mulched (Lal 1997). And interesting observation by Kirchhoff and Salako (2000) showed that after fallowing a degraded Alfisol caused by tillage and soil erosion in South-Western Nigeria for six years, in comparisons with soils under tilled and no tilled plots indicates that soil degradation caused by tillage cannot be easily obliterated, and they suggested that conventional tillage should be avoided while conservational tillage be practiced when tillage is adapted.

Irrigation is another human activity that can result in soil degradation through its influence on salinization, acidification and alkanization, which could originate either from soil or irrigation water. Depending on the method, irrigation could be facilitating crusting and impenetrable layer. For instance, salinization and sodification,

impenetrable layer and crusting are a major constraints debilitating crop production in Chalawa irrigation Scheme in Kano State, Nigeria (Malgwi, 2008). Ayoade noted that too much irrigation leach out soil nutrient, raise water table which can cause salinisation of soils as well as cause water lodging situation which encourage accumulation of iron compound leading to decrease in soil air, and little irrigation especially in the Sahel region on the hinter land causes salt accumulation on soil surface, while continuous wetting and drying of the surface results in crusting.

Gruhn et al. (2000) pointed out that deforestation, over-exploitation, over grazing, agricultural activities and industrial activities are human-induced causes of soil degradation. The extent of this human-induced soil degradation in some parts of the world is illustrated in table 1.1

Table 1.1 the extent of soil degradation in various regions of the world

Regions	Deforestation	Over Exploitation	Over Grazing	Agricultural Activities
Africa	13.6	12.8	49.2	24.5
Asia	39.9	6.2	26.4	27.3
South America	41.0	4.9	27.9	26.3
World	29.5	6.8	34.5	28.1

Source: Oldman (1992)

From this table, African rate of over exploitation and over grazing is greater than the world average with deforestation and agricultural activities remaining relatively lower. The debilitating effect of these human induced causes of soil degradation is of

accelerating soil degradation processes.

The effects of over grazing and deforestation are those of depletion of surface cover, compaction of the soil due to trampling which destroys the soil structure and texture. Over exploitation and bad agricultural practices leads to soil nutrient mining and soil quality deterioration (Gruhn et al., 2000; Ayoade, 1993).

Important human-induced soil degradation is bush burning and forest fires. In the last few decades, there has been increase awareness that wild fires and prescribed fires can also have profound effects on the function of the soil system (Stefan and Arterni, 2005). In some researches carried out in isolation shows that fires affects the physical, biological and chemical properties such as changes to aggregate stability, pore size distribution, water repellency ,and runoff response, alteration in mineralization rate, biomass production, microbial species composition and carbon sequestration as well as changes in C: N ratio, PH and nutrient availability (Debano et al, 1976; Chandler et al, 1983; Neary et al, 1999; Gonzace-perez et a1,2004).

Goforth et al (2005), reported that deposition of $CaC0_2$ in ash over the experimental plot in California of about 1.5ha-^{1}, where sufficiently heated to red, results in production of thermal maghaemite (r-fe_20_3), and concluded that fire changes over time influence soil genesis. D' Ascoli et al (2005) reported decrease in microbial community in the initial stage of fire but return to normal after 3 months and observed a stronger and longer lasting effect of fire on fungi than on bacteria in Mediterranean mountain of Italy.

U'bade et al (2005) in Mediterranean mountain noticed the effect of fire on all soil parameter which show a significant increase immediately after the fire but a year letter every thing return to pre-fire level. Guerrero et al (2005) noticed a strong enhancement in export of nutrients from the easily detachable ash layer decrease gradually over the first four 4 months due to exhaustion after which notable losses are only triggered by extreme rainfall events.

1.5.4 The Effects of Negative Nutrient Balance

Cumulative negative nutrient balances heighten the impact of climatic factors, insecure tenure arrangements, land and demographic pressure on soil fertility (Gruhn, Gelleti and Yudelman 2000). In 1993, seven million metrics tons of nitrogen, phosphorus, potassium, magnesium and calcium were depleted from soil in low-income countries of Bangladesh, Indonesia, Myanmar, Philippines, Thailand and Vietnam (Mutert, 1996). In sub-saharan Africa, net annual nutrient depletion was estimated at 22 Kg of nitrogen, 2.5 Kg of phosphorus and 15 Kg of potassium per hectare during 1987-94 (Stoorvogel, Smalling and Janssen, 1993).

The cumulative effects of yearly negative nutrient balance on crop yield are often seen through the impact of soil erosion on productivity (Gruhn, Guletti, and Yudelman 2000). In the United States for example, if the present erosion rate continue and inputs are managed effectively productivity could decrease by five percent over the next 100 years (Hagen and Dyke, 1980; Gruhn, Goletti and Yudelmim 2000), with regional variation ranging from 0.7-7.1 percent (USDA, 1990), but it is suggested that with modern integrated management and conservation practices could lower the projected erosion-related, productivity losses to about 2

percent over the next 100 years (USDA, 1989).

In many parts of the developing world where poor soil conservation and management method prevails, long-term productivity is projected to decline substantially unless soil management practices improves (Gruhn, Goletti and Yudelmim 2000). In Africa, it is reported that past erosion has reduced average yield by 10 to 20 percent over the pass 100 years (Dregne, 1990 and Lal, 1991). In fragile areas of South-Eastern Tunisia, erosion has reduced long-term productivity by more than 50 percent (Dregne, 1990). Scher and Yadav (1996) projected that if this trend continues unabated yield may decrease by another 16.5 percent in Asia and 14.5 percent in Africa by 2020.

1.5.5 Soil Health and Monitoring

Soil health is used synonymously with soil quality and soil condition (Lobry de Bryun and Abbey 2003). However, the most accepted definition of soil health was given by Doran and Parkin (1994) as the capacity of the soil to function within ecosystem boundaries to sustain biological productivity, maintains environmental quality, and promote plant and animal health. Lal (1993) move a step further to give us the diagnostic characteristics of soil health acting over time using a model.

Soil health = f(Pi x Sc x Rd x P x Ed x Nc x Bd) T

Where Pi is productivity, Sc is soil structure, Rd is effective rooting depth, P is total porosity and pore size distribution, Ed is charge density, Nc is plant available reserves, Bd is biodiversity and T is time. Part of the definition of soil health is the ability to quantitatively determine an index of soil health as well as compose relationship between soil properties, though how this is to become operational and part of mainstream of monitoring is less clear. In fact, some scientists consider it

impossible to quantify soil health. The types of indicators under development by scientist to monitor the state of the soil resource would include range of soil physical, chemical and biological properties that are highly analytical and unlikely to be used by farmers, yet scientists still perceive this as a plausible option (Lobry de Bryun and Abbey, 2003).

1.5.6 Soil Fertility Management Practices

Soil Fertility Management (SFM) is a basis for sustainability in agricultural production system, which involves the creation of favourable condition for soil life and plant growth, nutrient application and conservation (ILEIA Newsletter, 1997). Many different practices influence soil fertility including; the application of organic or synthetic fertilizer, green manuring, mulching, burning, soil tillage, soil and water conservation, crop rotation as well as animal and tree integration.

Soil Fertility Management (SFM) is a complex issue involving many farming practices. Each farming system with its own unique way of SFM which depends on combination of factors, these factors includes; the condition of the natural resources and their relative prices, the history of local farming, farming knowledge, their motivation, skills and degree of market orientation, the relative prices of inputs and agricultural policy.

Following these factors however, it is possible to identify different categories of farming system as shifting cultivation and fallow system base on natural processes of soil fertility regeneration (Cain, 1997), interactive pastural and fallow systems base on nutrient harvesting by animals and fallow vegetation, integrated organic agriculture

typified by the re-cycling of nutrients, and modern agriculture in which synthetic fertilizers and mechanization control. Within and between these practices is a wide diversity of practices.

1.5.7 SFM Practices in Nigeria

The benefits of the use of livestock manure in crop production are improvements in soil physical properties and provision of NPK and other mineral nutrients. The application of livestock manure increase soil organic matter and this lead to improved water infiltration and water holding capacity as well as increase Cation Exchange capacity (CEC). Manure and urine raise the pH level and accelerate the decomposition of organic matter contents and termite activity (Brouwer and Powell, 1998). If inorganic fertilizer, especially nitrogen, is combined with manure reduces soil acidity and improves the nutrient buffering capacity and the release of nutrient. Crop response, tree biomass production and changes in soil fertility characteristics were monitored in a long-term (1986-2002) alley cropping trial in Ibadan Nigeria, shows positive improvement in the observed parameters. In the South-East, alley cropping, green manuring and mulching improves soil condition and reduces soil degradation (Vanlawe et al, 2005).

Mortimore et al. (1990) established that integrating livestock and crop system has lead to small increase in nutrients, despite crop intensification and labour input increase with population density, using Kano close-settle zone as case study, an area under intensive cultivation for centuries. Hoffman (2001) also pointed that farmer's combine crop planting pattern and application of organic and mineral fertilizers in an effective ways to maintain the fertility of their soils in Zamfara. He stated that

management practices help reduce risk of crop losses and smoothen yield variation, as farmers do not aim at maximum but reliable yield even in years of bad rainfall.

One of the problems of SFM is the cost of adopting the strategies, for instance, where labour is scarce (extensive agriculture) or relatively expensive compared to the cost of synthetic fertilizers (modem agriculture), farmers can not afford labour intensive recycling of organic waste like that being initiated in Egypt (Cains 1997). In Nigeria, it is shown that farmer's strategies to improve soil fertility on their land holding through sue of animal manure or village refuse depend on their ownership of livestock, to provide the manure, and animal traction to transport manure from house hold or common access village refuse heaps to the fields (Harris 1999).

Guerin (2000) identified that limited adoption of land management research has been caused by presentation of research findings in a general form, which is not site or season specific, and is often difficult to integrate into existing work practices.

1.5.8 Summary of Literature Review

A healthy soil must function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and animal health. When this inherent ability of the soil is hampered, the soil is degraded. Once the soil of a place is put into use, a lot of soil degradation processes are triggered. But of all the human activities that result in soil degradation, cultivation is the most prominent. Cultivation as the most important cause of soil degradation affects soils through tillage practices, irrigation, burning, grazing and crop harvesting. These practices have their benefits in soil improvement but if not managed appropriately, deteriorate soil's quality through

their effects on bulk density, water content, penetration resistance, soil temperature, soil aggregate stability, soil nutrient base, organic matter and soil reaction.

For soils to function within sustainable limits, it must be managed in a way to enhance nutrients cycling, resilience and have minimal affects on the soils physical properties. Soil fertility management is a basis for sustainability in agricultural production, which involves the creation of favourable conditions for soil life, plant growth, nutrient application and conservation. Each farming system has it own unique way of soil fertility management.

However, soil health monitoring requires the prior knowledge of the soil initial conditions and the traditional soil management practices that culminates into the present soil condition. This would help in understanding the path and rate of soil degradation and the effectiveness of the traditional management practices.

CHAPTER TWO

THE ENVIRONMENT OF THE STUDY AREA

2.1 location of the Study Area

Gwagwalada is located between lat 8^{o} 50^{1} to $9^{o}00^{1}$ and long 6^{o} 50^{1} to $7^{o}09^{1}$ in the FCT. It is bounded to the east by the Federal Capital City (FCC), to the south by Kwali area council, to the west by Abaji Area Council and to the north by Niger state (see Fig. 2.1).

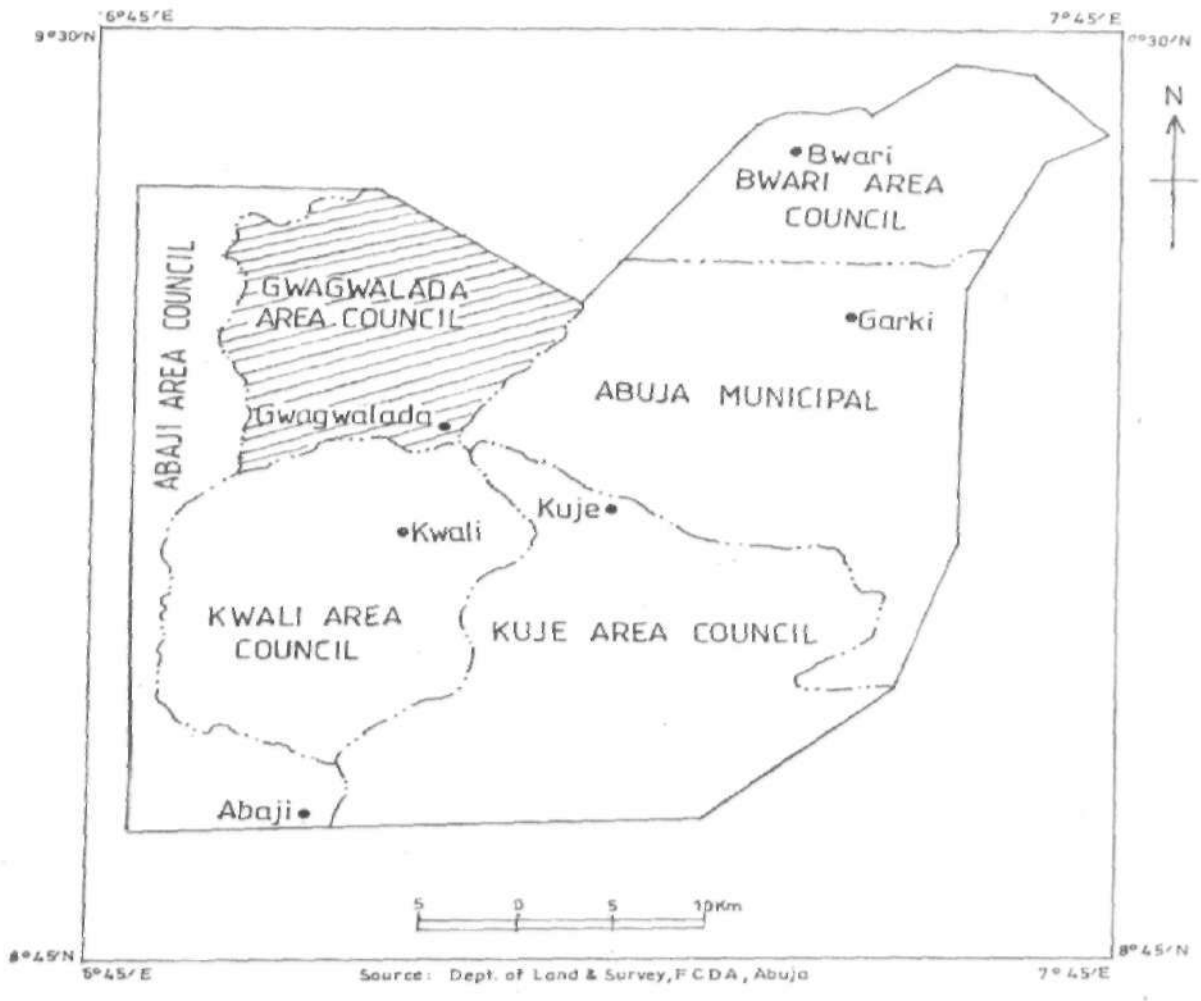


Fig. 2.1 The FCT Showing Gwagwalada Area Council

2.2 Physical Environment

2.2.1 Geology

There are two broad geological regions in the Federal Capital Territory (FCT), each with broadly similar structure and lithological characteristics. The first comprise the Basement Complex rock and account for more than 80 percent of the total area. The second consists of sedimentary rock in the South and south-West, forming part of the Nupe sandstone (Mabagunje, 1976), these are shown in figure 2.2.

The basement complex rocks are of three broad categories. The commonest are the granites and granite gneisses, many of which are banded. These kinds of rocks are found in Zuba dissected terrain. In some areas gneisses also form extensive hills but in this case the landscape tends to be low laying and almost flat or gently undulating. The second group of the basement complex rocks consists of the quartzose metamorphic rocks, notably, the quartz schist's and feldspathic quartz schist's pegmatities are associated with these rocks in many occurrences. These rocks have undergone some weathering and usually have thin covering of stony soils. Thus, the wooded ridges that are found on the Iku plains are composed of quartz and, feldapathic quartz schist's. Finally, there are the more basic igneous and metamorphic rocks such as diorite, hornblende schist's and biotitic schist's and gneisses, which underlie some of the low relief but are not common in Iku-Gurara plain.

Alluvial deposits are also found on the Gurara flood plain where it flows through the Nupe sandstone but do not constitute a major soil parent material in the area. Precambrian magmatic, gneisses, granite and schist of the crystalline basement complex almost predominantly underlie Gwagwalada area. Schist belt outcrops along

the South western margin of the area and the alluvial deposits are found in the Usuma River Channel (Gwagwalada Master plan, 1980)

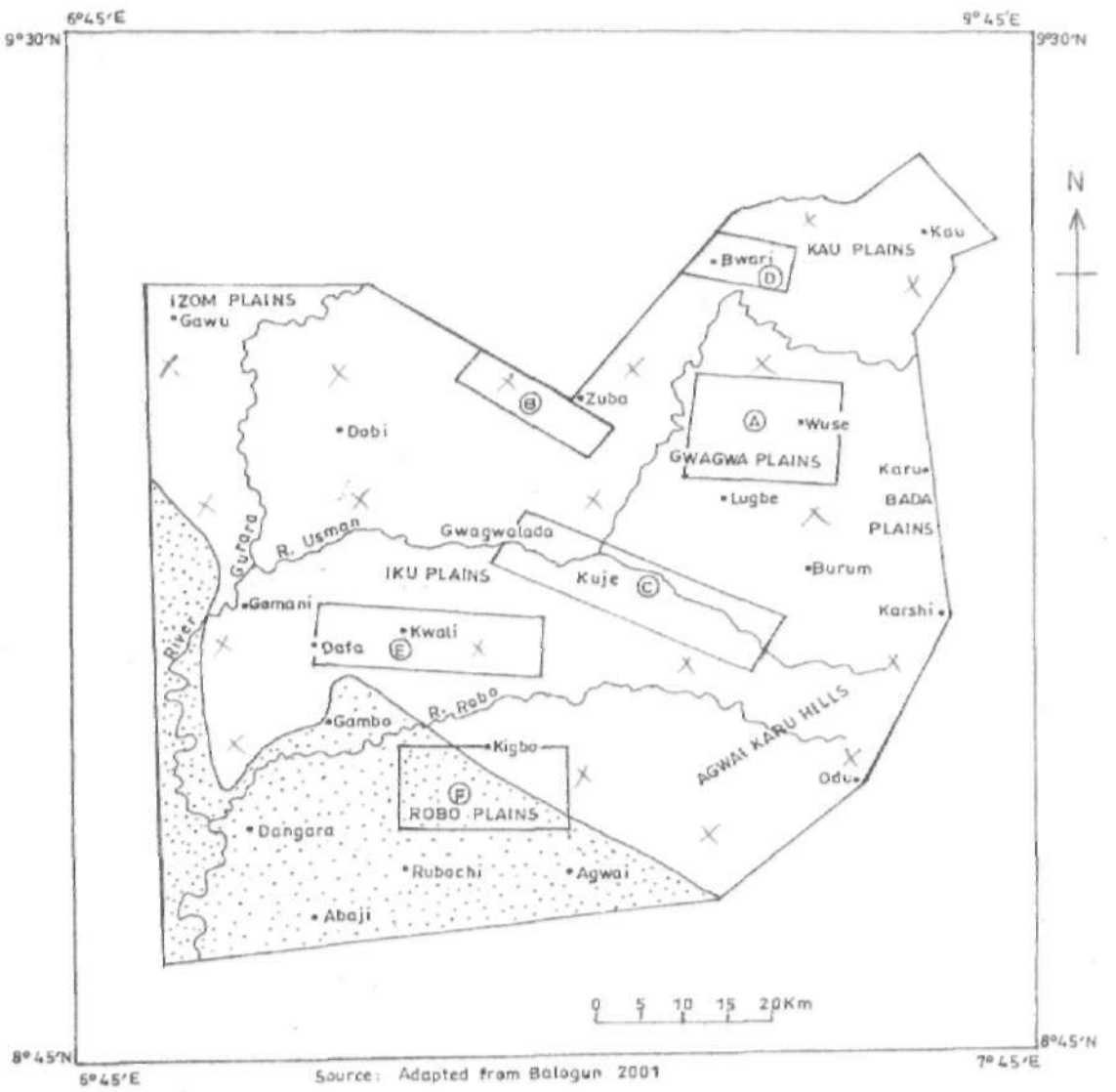


Fig. 2.2 Major Land System of the FCT

KEY

	Basement Complex
	Sedimentary Formations
A	Gwagwa Plains
B	Abuja Dissected Terrain
C	Kuje Plains
D	Kau Plains
E	Iku Plains
F	Robo Plains

2.2.3 Climate

Gwagwalada, being part of the Federal Capital Territory (FCT), falls under the tropical sub-humid climate with distinct dry and wet season with high temperature throughout the year. The climate is classified as the Aw according to Koppen's classification scheme.

The sunshine duration ranges from 8 to 9 hours daily, but increase in cloud cover during the months of July, August and September drops the sunshine hours per day to the average of about four hours (Adakayi, 2000).

The climate is influenced by two distinct winds (South-easterlies and North-westerly). These winds influences the seasonal variation in the FCT, they are the Tropical Continental Air Mass (North-westerly) and Maritime air Mass (South-easterlies) that determines the seasonal variation in West Africa. Maritime Air Mass carries the moisture- laden winds that bring about rainy season in West Africa while the Tropical Continental Air Mass is dry and dusty and bring about dry season in West Africa. The affect of Maritime Air Mass is felt in Gwagwalada somewhat between late February or early March to mid-October or early November when this air mass blow across West Africa hence, rainy season. While the effect of Tropical Continental Air Mass is felt in the area between mid- October or early November to late February or early March.

Temperature in Gwagwalada records its highest value during the month of March which is between 39.0^0 to 40.1^0 and its lowest in December which ranges between 17.2^0 to 19.1^0 using 10 years analysis of temperature records in Gwagwalada (Madaki,

2005). The diurnal range of temperature in the analysis reveals the month of January as having the highest value with its lowest value in September, the highest of 16.7^0 and lowest value of 7.0^0.

Relative Humidity (RH) raises every where during the rainy season and falls considerably during the dry season. In the afternoon, RH rises to above 60 percent during rainy season and falls to as low as

30 percent during the dry season (Hassan, 1997). The month of January has been shown to record the lowest RH of between 34.2 to 52.0 percent and the highest in the month of August ranging from 82.9 to 95.0 percent in 10 years analysis of RH of Gwagwalada (Madaki, 2005).

The onset of rainy season starts from late February to middle of March on the average and ceases in mid-October and some time early November. The rainy season is characterized by double maxima. The duration of the rainy season ranges between 240days to 190days. The mean annual rainfall varies from 1145 to 1631mm (Hassan 1997), with 60percent of the annual rainfall during the months of July, August and September. Another important feature of the rainy season in this area is the frequent occurrence of squall line heralded by thunder storms, lightening, strong winds and rainfall of high intensity, particularly at the beginning and end of the rainy season.

2.2.3 Geomorphology of the Study Area

Gwagwalada includes areas extending from Zuba dissected terrain to the extensive Iku-Gurara plain (Chups, 2000), covering about $52km^2$ (Mabagunje, 1976), illustrated

in figure 2.3. We can hence, discus the geomorphology under two types of land forms.

2.2.3.1 The Dissected Terrain

The dissected terrain is an area of high hills and dissected landforms running due south from Abuja City to a little distance North of Gwagwalada-Kuje road. Along the eastern and western boundaries are discontinuous ranges of hills (wuna and Idon kasa), that rise to almost 610m a.s.l in some places. In between these ranges is a strongly undulating plain from which rise a few isolated hills. This area of plain terrain is connected to iku plains in the west by low gap in the Wuna ranges and to the Gwagwa plain in the east by the gap through which the Gwagwalada-kuje road passes. Absolute relief varies between 244m and 305m asl, but reaches over 600m on individual peaks of the ridge. Over 98 percent of the area has average slope of less than 6^0, steeper gradient being associated with the steep-side ridges.



Fig. Physiographic Regions of the Federal Capital Territory

KEY

Hill & Disected Terrain

Undulating Plains

2.2.3.2 Iku-Gurara Plain

The Iku-Gurara plain lies west of the Abuja Hills and Dissected terrain and are the most extensive of the plains. It is an area of monotonously flat land dissected by streams with barely distinct channels. The absolute elevation is between 152m and 244m. Relative relief varies between 30m and 213m the mean relative relief for the area being 98m, swamps and flood plains are important elements of the landscape. The flood plain of River Gurara connects the Iku plains with the Robo and Rubochi plains. Line of hills runs across the plains Abuchi in the North West to Kayodaki in the south west, to the north west of the region and south of Izom are the Pagada hills from which River Itsu takes its source. Except on these hills, slopes are generally long and gentle, the characteristics slope angle in the area being 1.5^0. Drainage texture is coarse in the southern part of the region where valley density values are generally less than 1 per km^2. Coarse to medium texture is prevalent in the northern part of the plains. On the whole, Iku-Gurara plains can be said to be gently undulating, scoring an average roughness value of 4 according to Mabagunjes (1976) rating.

The table below summarizes the physiographic regions of the FCT

Table 2.0 SUMMARIES OF THE MAIN CHARACTERISTICS OF THE PHYSIOGRAPHIC REGIONS OF GWAGWALADA.

Physiographic unit	Elevation							
	Area (Km^2)	Max	Min	Average relative relief	Average slope	Average valley density	Average roughness number	Remarks
Hills and dissected terrain	216.20	610	244	160	6.0	2.10	6	9
Iku-Gurara plain	1818.06	244	152	98	0.58	0.81	4	1

Source; Akin Mabagunje (1976)

The area drains south into River Usuma and North-West into River Iku and Itsu which all drains into River Gurara (shown in figure 2.4). Texture of the dissection is moderately course, averaging 2 per km^2. The Northern 60 percent has valley density values ranging from 2 to 4 per km^2. The terrain is therefore moderately rough scoring roughness value of between 3 and 10 according to Mabagunnje (1976) rating.



Fig. 2.4 Drainage Map of the FCT, Nigeria

KEY
Hydrological Stations
Dams
Water Shed

2.2.4 Soils

Based on topographic relation, soils of Gwagwalada are classified into 3 broad groups (Mabagunje, 1977). These are soils of the lower slope, middle slopes, upper slopes and the summits. The soils of the lower slopes are characterized by the presence of lateritic iron pan, with a dark brown coloured surface horizon and turn through strongly mottled yellowish brown into a light grey horizon. The texture becomes at depth sandy clay loam to clay between 40 and 60cm. there are abundant iron concretions that are weakly cemented. The soils are classified as FERRIC ACRISOLS, petric phase with ground water at 50cm.

On the middle slopes, the unmottled surface horizon being very dark grey brown in colour. The deeper unmottled surface horizon turns yellowish-brown into redish yellow at depth and is within 100cm of the surface underlain by a hardened iron pan. The soils are ORTHIC ACRISOLS petroferric phase.

The soils of the upper slopes and summits of the interfluves show the tendency to turn in colour from yellowish brown to reddish yellow in the upper slopes to yellowish red or red on the summits. The slopes are between 0° and 1°. The soils are unmottled and have no inclusions. The texture at depth is sandy clay loam to clay loam. The soils are classified as ORTHIC ACRISOLS.

The Soils of upper slopes and summits, in these dissected plains soils may vary considerably in morphological characteristics. The summits are convex; the soils are very stony in the upper horizon with over 40percent inclusions to a depth of some 30cm. The content of the inclusions then decreases and the soils within 100cm of the surface are underlain by strongly weathered rock which still have an outstanding rock

structure with an unmottled red and very gravely sandy clay to clay loam horizon. The inclusion is clearly colluvial and consists of rock fragments with dark mineral originating from the surrounding hills mixed with schist fragments. With depth, the content of the inclusions decreases to some 5-10 percent and the soils are then overlying strongly weathered schist's. Depending on their location in the unit, the slopes very considerably from 2°-3° above fedamas to 8° and over, above deeply incised gullies. The soils are classified as ORTHIC ACRISOLS with stony and lithic phase.

2.2.5 Vegetation

The vegetation of Gwagwalada can be classified as park savannah, with scattered trees and tall grasses. There are however, some wooden areas along interfluves between the Usuma river and its tributaries (Gwagwalada Master plan, 1980). The vegetation is made up of heterogeneous species of trees and grasses comprising *of Afalia Africana,Lerminalia macropeta, Daniella oliveri, Parkia biglobosa, vitex daniana, ceiba peptendra, bomba costatum and khaya grands* to mention but few. The species of grasses in this area include *andropogon gayanus, andropogan pseudapricus, bexeropsis uniseta etc.* Though, most of the species of vegetation have been depleted to give way for development and agricultural production except on a hilly and rugged terrain where cultivation is almost impossible, the vegetation is use for pasture and wood harvesting.

2.2.6 Land Use

The land of this area are put into various uses, but can be categorized into three. They include residential, commercial and agricultural land uses (Balogun, 2001). But in this

work the focus is on agricultural land uses. Apart from the village of Gwagwalada and Pasum, the area lies within an agricultural zone with much of the land heavily cultivated (Gwagwalada Master Plan 1980). The cultivation of land is mostly manually and shifting cultivation method is generally practiced. Around Gwagwalada, land is cropped for 4-6years, and then allowed to rest for 3-4years period (Gwagwalada Master Plan, 1980) and there is few mechanized farming in the area (Balogun, 2001). The primary food and cash crops in this region are yams and sorghum, although maize, cowpeas, groundnut, garden eggs cassava and rice are commonly grown.

The people of Gwagwalada area are also engaged in livestock farming, the livestock includes cattle, sheep, goats, pig and poultry among others. Thus, small available data has shown the number of cattle in the area was 619,275 that of sheep were 510,012 that of goats were 45,891 and that of poultry were 3,705,221 in 1995 (Garba 2000).

2.2.7 The Implications of the Physical Environment to the Soil Fertility of the Area

The geology of the study area have the implication of forming mostly sandy loam to sandy clay loam soils of low inherent fertility. The climate of the area would influence high mineralization, leaching and lost of nutrient through surface wash. Hence, there is likelihood of having soils with low organic matter content, weak soil aggregation that is susceptible to surface wash with high acidity. The geomorphology of the area is that, which would influence high infiltration rate, high water content and nutrient retention capacity on the extensive Iku-Gurara plain. While that of Zuba dissected terrain would influence high erosion rate, reduced infiltration rate, low

moisture content and organic matter and hence high bulk density. The soils of the area being Acrisols, are mostly highly weathered acid soils with low base saturation. This types of soils are generally paucity of plant nutrients, alluminium toxicity, strong phosphorus sorption and slaking/crusting. The soils are largely not very productive. The area is within the area of light forest with abundant grasses and few scattered trees, hence, there would be high organic matter turn over from the grasses, herbs and shrubs within the root zone.

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CHAPTER THREE

METHODOLOGY (MATERIALS AND METHEDS)

3.1 Introduction

This chapter describes the materials and methods employed in this study, the methods include field survey, selection of farming communities and farmland, soil sampling, laboratory analysis, soil management survey and analysis of data.

3.2 Types and Sources of Data

The types of data employed in this work are primary data for both soil fertility survey and farmers' management practice survey. The data are sourced from the field and laboratory analysis.

3.3.0 Soil Fertility Survey

This survey was carried out in two phases. The first was reconnaissance survey and the second was the field survey.

3.3.1 Reconnaissance survey

Reconnaissance survey of the area council was conducted with the objective of getting acquainted with the area council, especially the diversity within the area council, such diversity as the vegetation cover, settlement pattern, the land system, the land use pattern and soil changes. Although, there is a great similarity in cultural setting and land use pattern, and even the soils and vegetation, especially on the extensive Iku-Gurara plain, but there are some fundamental discrepancies on the environment of the Zuba dissected terrain. On this basis, the outcome of the reconnaissance survey was the selection of seven farming communities. They include

Dadabiri, Ledi, Gurfata, Paikon Kore, Giyabiri, Giri-Wuna and Tungan Mallam Hassan farming communities. The figure 3.1 bellow shows these communities.

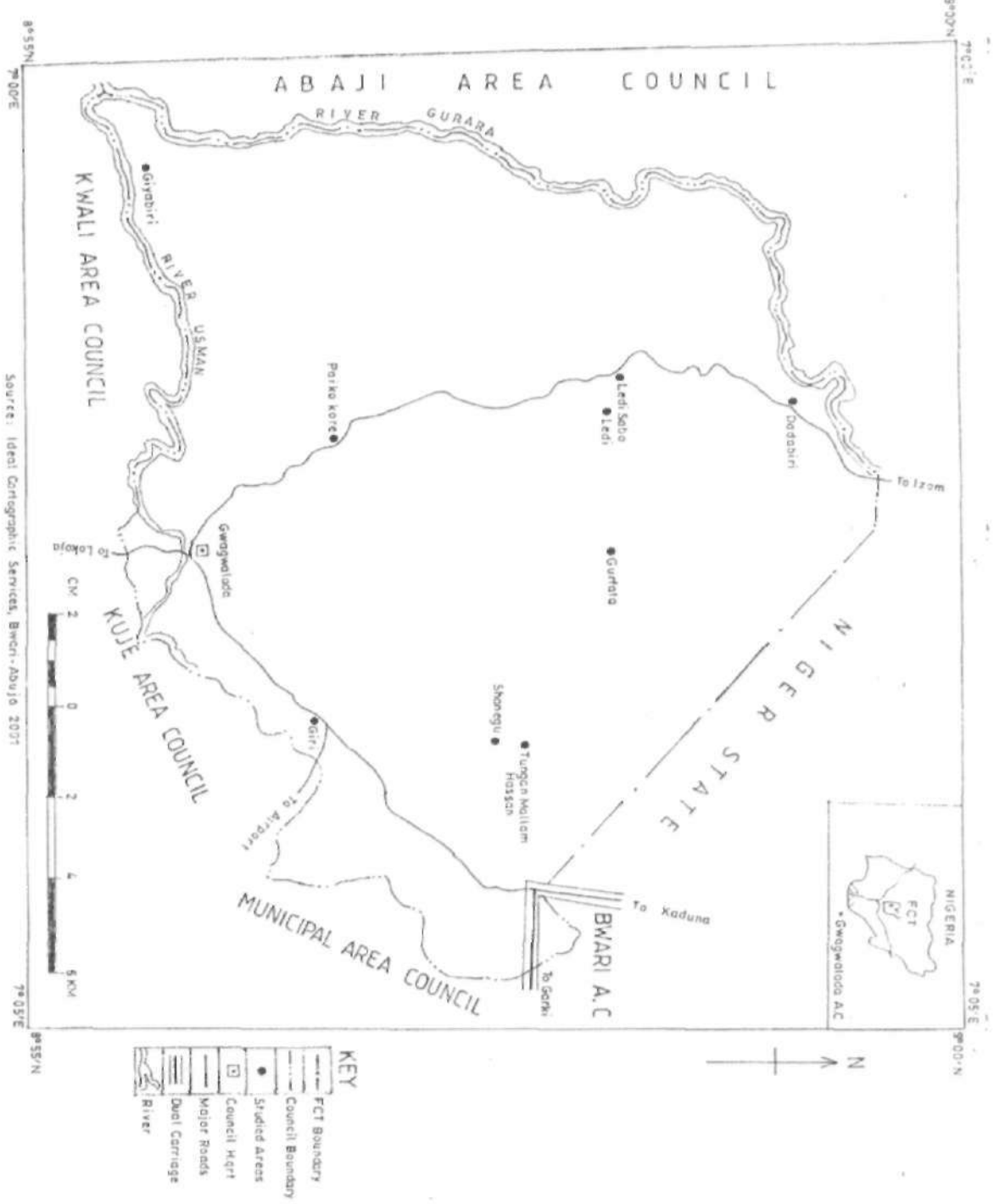


Fig. Gwagwalada Area Council and Studied Areas

Source: Ideal Cartographic Services, Bwari-Abuja 2007

3.3.2 Field Survey

In each of the seven selected villages, three traverse walk in radial pattern from the centre of the village was taken and at least one farm plot of some 0.6 to 1 hectare were selected along each traverse . A total of four farm plots were selected in each selected village.

For the purpose of soil inspection and sampling, each plot identified and selected for survey, was sub-divided into eight sub plots and four of them were randomly selected. Surface (0-15cm depth) soil samples were taken from four evenly spaced points over each plot and the samples prepared and bulked for laboratory analysis.

In addition to sampling, over four farm plots in each of the villages, an additional plot, at an adjacent location, under long standing fallow were sampled to serve as a control for the other farm plots. Thus, on the whole, five bulked sampled soils were taken from each village, making 35samples all together for the study.

3.4 Laboratory Analysis of Samples

The following key soil fertility indicators were determined from the soil samples collected; texture, pH, Cation Exchange Capacity (CEC), exchangeable cations (Ca, Mg, K and Na), exchange acidity (Al+, H+), organic carbon, available phosphorous and total nitrogen.

3.4.1 Particle size distribution

This was determined using the pipette method. In this method, the samples were air-dried and from each, 50g sub-sample was taken which was then crushed gently in a

mortar. Using a 2mm sieve, the gravel fractions were removed from the crushed soil sample and from that a 25g sub-sample was again taken, it this 25g that was used for the particle size analysis.

To ensure that the particle sizes are in separate form, each of the 25g sub-sample was treated with sodium hexametaphosphate (calgon) and left for some hours to react completely with the samples. The suspension was then poured into a measuring 1000ml mark cylinder and some distilled water added to make it to 1000ml mark. This was then stirred for 30 second to ensure proper and through dispersion. It was then allowed to settle for 3 minutes 30 seconds. With the aid of a pipette, representative fractions of clay and silt were taken for different farm communities using Stoke's law. The sucked mixtures were then poured into an evaporating dish and then ovum dried at 105° after which the weight of silt and clay fraction and their percentages were determined as follows:

% silt (0.05 – 0.002mm) + % clay (<0.002) =

$$\frac{w^z e}{25} \times \frac{1000}{w^a} \times \frac{100}{1} = \frac{40w^z e}{w^a} \times \frac{100}{1} = \frac{4000\, w^z e}{w^a}$$

$$\% \text{ silt} = \frac{w^c}{25} + \frac{1000}{w^a} \times \frac{100}{1} = \frac{4000\, w^c}{w^a}$$

% sand = (% silt + % clay) - % clay

Where:

$W^z e$ = weight of silt and clay

W^a = weight of air- dried sub-sample (25g)

W^c = weight of clay

The remaining suspension in the measuring cylinders were then carefully poured into an evaporating dish and then ovum dried. Using appropriate sieve, the fraction of sand was then separated into coarse and fine sand. The fractions of each of the sub-fraction (coarse and fine sand) were then estimated as follows:

$$\% \text{ fine sand } (0.50\text{-}0.05\text{mm}) = \frac{w^f s}{w^a} \times 100$$

$$\% \text{ coase sand } (2.00\text{-}0.50\text{mm}) = \frac{w^c s}{w^a} \times 100$$

where:

$w^f s$ = weight of fine sand

$w^c s$ = weight of coarse sand

3.4.2 Bulk Density and Moisture Content (g/cm^3)

The bulk density (BD) ring containing the collected soil samples was weighed and then ovum dried at 105° c for 24 hours after which it was re-weighed. Bulk density value was then determined as follows:

$$BD\ (g/cm^3) = \frac{\text{weigh of the soil}}{\text{Volume of the soil}}$$

Where:

Weigh of the soil (g) = weigh of the ring plus the bulk sample after ovum drying minus weigh of the ring.

Volume of the soil = volume of the ring (cm3).

Volumetric water (moisture) content was determined as:

$$VWC = \frac{Ws_1 - Ws_2}{Dw - Vs_1}$$

Where:

VWC = Volumetric water content (g/cm3)

Ws_1 = weight of the soil before ovum drying

Ws_2 = weight of the soil after ovum drying

Vs_1 = volume of the soil

Dw = Density of the water in the sample

3.4.3 Soil pH (1:2:5)

To determine soil pH, 20g of air-dried soil sample was taken in a 50ml beaker to which 20ml of distilled water was added. The suspension was then stirred several times for 30 minutes in order to allow most of the suspend clay to settle down. Electrodes of pH meter were then inserted into the partly settled suspension and the pH was then measured. While taking the measurement, the suspension was not stirred and the electrodes were not allowed to touch the bottom of the beaker, to avoid errors in measurement.

3.4.4 Soil Organic Matter (%)

This was determined using Walkey-Black digestion method. A representative samples was taken, grinded and passed through a 0.50mm sieve. 10gsub-sample was taken in a 250ml conical flask and 10ml of potassium dichromate ($k^2 Cr^2 O^7$) solution was then pipette accurately into 200ml and 500ml conical flask and swirled gently to disperse the soil. Then 20ml concentrated sulphuric acid was rapidly added to from a measuring cylinder. The flasks were then immediately swirled gently until the soil and the reagents were mixed. Next, the mixtures were swirled more vigorously for

one minute. Each flask was then rotated gently again and then allowed to stand on a sheet of asbestos for 30 minutes with a view to cooling the mixture.

Then, 100ml of distilled water was added after the cooling and then the mixture was allowed to cool again. Following this, four drops of indicator were added onto the mixture and titrated with 0.5N ferrous sulphate ($FeSo_4$) solution on a white background. After this was done, a blank determination was then made in the same way but without the soil with a view to standardizing the dichromate (PC) was then calculated using the formula:

$$PC = \frac{\text{Blank titre value} - \text{actual titre value} \times 0.3 \times m \times f}{\text{Weight of soil} - \text{air dried soil used}} \times \frac{100}{1}$$

Where:

PC = percentage carbon

f = correction factor 1.33

m = concentration of $FeSO_4$

Organic matter (%) was then calculated using the formula:

= % carbon x 1.729

3.4.5 Cation Exchange Capacity (CEC) (Me/100g)

The CEC was determined using ammonia acetate extraction method. 10g of air-dried 2mm sieved soil sample was weighed into a 500ml Erlenmeyer flask and 40ml of neutral 1N ammonium acetate (NH_4OAC) was added. The flask was then shaken thoroughly and allowed to stand over night. The soil was then filtered with light suction using a 55mm Buckner funnels. Then the soil was leached with the neutral 1N NH_4OAC reagent until no evidence for calcium can be obtained in the affluent

solution. The leacheate was then preserved for the determination of exchangeable bases. Next, the soil was again leached four times with 250ml each of 1N ammonium chloride (NH_4Cl) and once with 250ml of 0.25N NH_4Cl. The electrolyte was then washed out with 200ml of 99N ethyl Alcohol. When the chloride in the leachate (which was using 0.10 N silver nitrate) became negligible, the soil was allowed to drain thoroughly.

The soil was then transferred and filtered and filtered into 50ml Kjedahl flask and 250ml of distilled water was added. Then, few drops of liquid paraffin, pumice beads (to prevent fuming and bumping) and 10ml of 1N sodium hydroxide were added, about 60ml of the solution which was measured into 250ml Erlenmeyer flask. 10 drops of bromocresol green-methyl-red mixed indicator were added and ammonium borate was titrated which was produced with standard 0.02 N sulphuric acid solution. Following this, blank were run on the reagents and the titre results was corrected with the blank result. The CEC in me/100g of CEC soil was then calculated using the formula.

$$\text{CEC (me/100g)} = \frac{(T-B) \times N \times 100}{W}$$

Where:

N = Normality of the acid used

W= Weight of the sub-sample

T = titre volume of the acid used in titration

B= Blank titre volume used

3.4.6 Total Nitrogen (%)

This was determined using regular macro kjeldahl method. To do this, 20g of soil was weighed into kjeldahl flask and 20ml of distilled water was added and the flask was swirled for 60 minutes and allowed to stand for 30 minutes. Then 3g of catalyst and 20ml of concentrated sulphuric acid (H_2SO_4) were added. the mixture was then continuously heated slowly until the water was removed a frothing has ceased. The mixture was then boiled for 5 hours during which the heat was regulated so that the $H_2 SO_4$ condensed half way up the neck of the flask. The flask was then allowed to cool. The digest was carefully transferred into another clean flask. The sand particles were retained in the original digestion so as to prevent the particles from causing bumping during distillation.

Next, the sand residue was washed with 50ml of distilled water for about four times and made to mark with distilled water. 10ml of boric acid solution was then added into 500ml Erlenmeyer flask which was then placed under the condenser of the distillation apparatus with the end of the condenser placed 4cm above the surface of the boric acid solution. 10ml of 4% sodium hydroxide (NaOH) was slowly added into 10ml of the digest which was attached to the distillation apparatus. The mixture was then heated until it boiled.

Sufficient water was allowed to flow through the condenser to allow it to cool (to below 30°). When about 50% of the distillate was collected, the distillation was stopped. Ammonium, which was liberated from the H_2SO_4, was titrated and 3 drops of indicator was added until the colour changed from green to pink. A blank

determination was then run without the soil sample. The percentage Nitrogen (PN) was then calculated using the formula:

$$PN = \frac{0.014 \times N \times 100 \times TV}{\text{Weight of soil uses} \times AD}$$

Where:

PN = percentage Nitrogen

VD= volume of digest

N = Normality of acid

TV= Titre value

AD= Aliqout of digest

3.4.7 Exchangeable bases (me/100g)

The leachate which has been preserved during the CEC determination was used to determine the exchangeable bases (namely calcium, magnesium, potassium and sodium). Standard readings were used for different concentrations of each cation to plot a graph of adsorbance Vs concentration (ppm) of each base. Calcium and magnesium were determined using atomic absorption spectro-photometer while potassium and sodium were determined using flame emission method. The me/100g of each base was then calculated using the formula:

$$Me/100g = \frac{\text{ppm graph} \times VE \times DF \times 100}{1000 \times W \times \text{Equivalent weight of the element}}$$

Where:

VE = Volume of extractant

DF = Dilution factor

W = Weight of soil sample used

3.4.8 Available phosphorus (ppm)

This was determined using Bray No 1 method. To do this, 1g of air-dried soil was weighed into a 15ml centrifuge tube and 7ml of extracting solution was added and the mixture was shaken for 1 minute on a mechanical shaker. The suspension was then centrifuged at 2,000 rounds per minute for 15 minutes and was then decanted into an acid washed volumetric flask. The phosphorus in the extract was then determined using ascorbic molybdate blue method. This was done by pipetting 3ml of distilled water was then added to it.

Next, a 4ml of 0.5N hydrochloric acid was added and the mixture was then allowed to stand for 15 minutes for the colour to develop. The p content was then determined in the extract on a spectrophotometer using spectronic 70, 50, 20 at 882 muo by percentage transmittance. A set of standard P solutions containing 0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 ppm respectively were prepared and used for blank determination to aid in reading off the ppm of P for the soil solution prepared.

3.4.9 Base Saturation (%)

This was derived through addition of the exchangeable cation values determined which was then divided by the CEC value and multiply the quotient by 100.

3.4.10 Exchangeable Sodium Percentage (ESP) and Sodium Adsorption Ratio (SAR)

ESP was derived by dividing the total sodium by CEC and multiply the quotient by 100, SAR by using the formula:

$$ESP = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

3.5 Management Survey

The aim of this section of the research is to audit the farmers' management practices in this area council. The farmer's management practices were assessed through structured interview with farmers in the respective villages. Total number of 82 questionnaires where administered in eight farming communities to assess the farmers' management practices. The information obtained includes those of the farmers age and their marital status, level of income, level of education, occupation, number of plots, sizes of plot in hectares, type of crops grown in the area, the use of crop residue to the farmers, fertility assessment and their indicating features, soil/land degradation it severity and causative factors and their soil conservation methods. Each section here is interpreted in percentage of the number of respondents.

A copy of the questionnaire is marked as Appendix B

In each farming community both old and young male farmers, were interviewed. Females were not included because in these communities women do not take an active part in farm operation. In addition to structured interview an oral interview of purposefully selected respondents including community and opinion leaders were also carried out.

3.6 Analysis of Data

The results of soil samples analyzed from the laboratory and information obtained from soil management survey were subjected to appropriate statistical analysis. A statistical package SPSS 2008 version was employed for the analysis of the results generated from the laboratory analysis of the soil properties. Two major statistical techniques were employed in the analysis of data on the soil properties. These are student t-test and one way analysis of variance. The t-test was applied to compare the data of the respective cultivated plots with other plots in other farming communities' i.e. pairing two cultivated plots, this statistical test is used in testing for the significant difference between two variables about a mean and standard deviation with normal distribution, hence, t-test is more appropriate for pairs of the cultivated plots. Analysis of variance on the other hand was employed to test for significant differences amongst data from all villages,

The soil fertility assessment was done based on the fertility rating adapted by Malgwi (2007). The rating is based on the USDA soil conservation system modified for Northern parts of Nigeria. The general interpretation required for profitable sustained agriculture is presented on page 48 based on the rating limits presented in Appendix C

Table 3.0 Table of rating of soil properties favourable for high soil fertility

a) **Physical properties**

Soil properties	condition favouring high soil fertility	condition unfavourable to high soil fertility
Depth texture	>150cm *Loam, sandy clay loam, sandy clay, clay* (if structure and consistence are favourable)	<150cm *Sand, loam sand, heavy clay*
Structure	Moderate or strong fine	Massive or coarse
Consistence	Friable	Very firm
Moisture condition	Free drainage with moisture retention	Impeded, low moisture retention and rapid permeability
Bulk density	1.0-1.5 (m-f texture) 1.1-1.65 (c. texture)	>1.5 >1.65
Porosity	50% in top 30cm	Low 2%

b) Chemical properties

Soil properties	condition favouring high soil fertility	condition unfavouring to high soil fertility
N, P, K, Ca, Mg, S	High levels	Low levels
Fe, Mn, Zn, Cu	High levels	Low levels
B, Co, Fe, Cl	Medium to high levels	Low levels
Reaction (pH)	Generally 5.6 - 6.5 5.0 – 8.0 but varies with crops	<4.5 >8.5
Salinity	Soluble salts and exchangeable Na low	High soluble salts and exchangeable Na
Organic matter	High	Low
Cation exchange capacity	>25 cmol (+)kg^{-1}	<6 cmol(+)kg^{-1}
Available P	> 20mgkg^{-1}	< 10mgkg^{-1}

Source: Soil Survey Staff, 1975 of USDA

Giving the nature of data generated from the farm management survey, mostly nominal data, hence, the data was discussed based on percentages.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results obtained from soil analysis; the data from the laboratory analysis of the soil samples obtained from the field work, the results of the statistical analysis used to show variation in the mean of the soil properties between the cultivated plots and adjacent long standing fallow plots (representing the control), variation amongst the soil samples of the various farming communities and between paired sampled plots.

4.2 Variation of soil properties across selected locations

Table 4.1 summarizes the status and variation of the examined soil properties across the different areas selected. It shows firstly, the variation in the mean values and the standard deviation (SD) of the soil properties over the respective seven cultivated study locations. It also shows the respective values for the nearby uncultivated long standing fallow plots representing the control sites. Finally, it gives results of the analysis of variance statistical test (ANOVA) employed to determine the level of significance of the differences in the values of the soil properties of the cultivated plots amongst the seven study locations. Table 4.2 on the other hand gives the results of the t-test employed to determine the level of significant differences in soil properties of the paired cultivated plots.

The descriptions of the results are given in the proceeding sub-sections. In the description of the results, the areas of concern are;

(i) the variation in the soil properties of the treated or cultivated plots over the different locations

(ii) comparison of the values for the treated plots with the respective control plots with the view of assessing the extent of degradation of the soil properties

(iii) Overall assessment of the fertility status of the soil properties.

The charts of the variation of the mean values are presented in Appendix A

Table 4.1 variation of soil properties of farms and control plots over selected sites

Soil properties	**Farming communities**							**ANOVA**
	A	B	C	D	E	F	G	*F-ratio for cultivated plots*
Sand (%) Cultivated plot								
$\bar{X}$	71.50	66.00	60.50	74.00	69.00	65.50	68.50	0.156
SD	5.26	3.80	12.20	2.50	5.20	13.90	4.10	
Control plot	68.00	64.00	62.00	61.00	68.00	63.60	68.50	
Silt (%) Cultivated plot								
$\bar{X}$	13.00	16.00	22.50	9.50	15.50	17.50	15.50	2.129*
SD	3.80	3.30	7.90	3.80	4.10	9.20	2.50	
Control plot	14.00	16.50	20.00	20.00	12.00	18.00	12.40	
Clay (%) Cultivated plot								
$\bar{X}$	15.50	17.50	17.00	16.50	15.55	16.30	16.00	0.323
SD	1.90	2.50	4.30	5.80	1.90	5.50	2.00	
Control plot	18.00	18.50	18.00	19.00	20.40	18.40	17.60	

Locations;

A =Giri-Wuna, B= Giyabiri, C= Ledi, D= Dadabiri, E= Paikon kore, F= Tungan Mallam Hassan, G= Gurfata

Level of significance: * =0.1; ** = 0.05; *** = 0.01

Bulk Density (g/cm^3) Cultivated plot								
$\bar{X}$	1.44	1.29	1.47	1.28	1.56	1.56	1.50	3.227*
SD	0.02	0.02	0.12	0.06	0.12	0.08	0.05	
Control plot	1.24	1.20	1.10	1.12	1.37	1.27	1.41	
Water Content (g/cm^3) Cultivated plot								
$\bar{X}$	0.25	0.24	0.15	0.21	0.23	0.10	0.12	3.227*
SD	0.02	0.35	0.01	0.01	0.11	0.00	0.01	
Control plot	0.13	0.19	0.20	0.20	0.25	0.14	0.28	
Organic Matter (%) Cultivated plot								
$\bar{X}$	1.65	1.89	1.68	1.90	1.51	0.96	1.38	0.713
SD	1.06	0.41	0.86	0.52	0.71	0.34	1.11	
Control plot	2.35	1.25	2.97	3.03	3.18	2.77	1.90	
Total N (%) Cultivated plot								
$\bar{X}$	0.06	0.08	0.07	0.08	0.04	0.06	0.06	1.498
SD	0.03	0.04	0.03	0.02	0.01	0.03	0.01	
Control plot	0.05	0.04	0.07	0.11	0.09	0.12	0.05	
Avail. P (ppm) Cultivated plot								
$\bar{X}$	24.06	28.44	25.38	26.69	9.41	16.63	9.41	1.061
SD	13.20	26.39	18.44	21.78	1.94	7.36	1.94	
Control plot	15.75	70.00	28.00	50.75	19.25	15.75	15.75	
Exch. Ca(me/100g) Cultivated plot								
$\bar{X}$	9.00	6.90	9.45	6.60	5.60	6.09	5.90	1.09
SD	3.56	1.00	5.74	1.63	1.18	2.09	1.07	
Control plot	12.00	10.00	12.00	26.00	16.00	14.00	5.90	
Exch. Mg (me/100g) Cultivated plot								
$\bar{X}$	2.24	2.20	2.79	3.07	1.87	2.64	2.07	1.779*
SD	0.94	0.35	0.44	0.44	0.33	1.81	0.16	
Control plot	2.71	2.64	4.63	7.18	3.70	3.47	2.15	
Exch. Na (me/100g) Cultivated plot								
$\bar{X}$	0.30	0.31	0.24	0.24	0.23	0.22	0.21	4.965***
SD	0.04	0.06	0.01	0.03	0.02	0.02	0.02	
Control plot	0.28	0.26	0.23	0.24	0.24	0.24	0.24	

Exch. K (me/100g)	0.22	0.19	0.31	0.27	0.28	0.32	0.22	1.20
Cultivated plot	0.09	0.07	0.11	0.08	0.12	0.08	0.03	
	0.29	0.46	0.34	1.23	0.39	0.29	0.25	
$\bar{X}$								
SD								
Control plot								
Base Saturation (%)								
Cultivated plot								
$\bar{X}$	95.96	96.28	97.56	94.57	97.01	96.55	96.62	1.306
SD	1.44	2.46	0.97	2.61	1.08	1.03	0.96	
Control plot	97.45	94.35	98.85	98.86	97.13	98.90	95.15	
CEC (me/100g)								
Cultivated plot								
$\bar{X}$	12.20	9.94	13.09	10.73	8.37	10.43	8.72	1.063
SD	4.58	1.06	6.18	1.80	1.17	3.35	1.25	
Control plot	15.68	14.16	17.40	25.05	20.93	18.19	18.24	
Exch. Acidity								
Cultivated plot								
$\bar{X}$	0.45	0.35	0.30	0.55	0.25	0.35	0.30	2.282*
SD	0.10	0.19	0.12	0.19	0.10	0.10	0.12	
Control	0.40	0.50	0.20	0.40	0.60	0.20	0.40	
pH ($CaCl_2$)								
Cultivated plot								
$\bar{X}$	6.25	5.63	6.13	5.83	6.13	6.20	6.03	3.878***
SD	0.06	0.17	0.10	0.52	0.10	0.16	0.13	
Control plot	6.30	5.80	6.40	6.00	6.00	6.30	6.60	
pH (H_2O)								
Cultivated plot								
$\bar{X}$	7.13	6.08	6.75	6.73	6.75	6.65	6.83	10.679***
SD	0.29	0.32	0.06	0.17	0.58	0.06	0.19	
Control plot	6.80	6.00	6.80	6.60	6.50	6.80	6.60	
ESP (%)								
Cultivated plot								
$\bar{X}$	2.67	3.13	2.11	2.33	2.74	2.20	2.49	1.026
SD	0.93	0.90	0.80	0.61	0.52	0.49	0.49	
Control plot	1.79	1.84	1.32	0.69	1.15	1.26	2.91	
SAR (%)								
Cultivated plot								
$\bar{X}$	0.08	0.08	0.06	0.06	0.07	0.06	0.06	2.021*
SD	0.02	0.02	0.01	0.01	0.01	0.01	0.01	
Control plot	0.06	0.06	0.04	0.03	0.04	0.04	0.07	

Table 4.2 Results of t-test of soil properties between pairs of locations

Soil properties	A/B	A/C	A/D	A/E	A/F	A/G	B/C	B/D	B/E	B/F	B/G	C/D	C/E	C/F	C/G	D/E	D/F	D/G	E/F	E/G	F/G
Sand	1.69*	1.66*	0.85	0.68	0.81	0.90	0.86	3.5**	0.93	0.07	0.89	2.17*	1.29	0.54	1.25	1.73*	1.20	2.26*	0.47	0.15	0.09
Silt	1.19	2.17	1.3	0.89	0.91	1.09	1.52	2.6**	0.19	0.31	0.24	2.9**	1.57*	0.83	1.69*	2.14*	1.62*	2.6**	0.4	0.0	0.42
Clay	1.27	0.64	0.33	0.0	0.26	0.36	0.2	0.32	1.27	0.41	0.93	0.14	0.64	0.21	0.42	0.33	0.06	0.16	0.26	0.36	0.41
Bulk Density	9.4***	0.38	3.47	1.35	2.13	3.43*	2.08	0.21	3.07*	4.68*	5.62*	1.97	0.69	0.88	1.35	2.8*	3.91*	1.94*	1.67	0.55	0.87
W C	0.23	2.83	1.13	0.24	4.14*	1.71	3.53*	1.18	0.13	3.49**	4.27*	8.49**	1.06	9.0*	2.24*	0.27	21.0*	7.60	0.06	1.39	0.86
O M	0.42	0.05	0.44	0.22	1.22	0.34	0.43	0.05	0.92	1.08	0.85	0.44	0.31	1.55	0.42	0.90	3.03**	0.85	1.38	0.19	0.72
Total N	1.18	0.64	1.34	1.02	0.00	0.26	0.61	0.00	2.37*	0.86	1.18	0.81	2.36*	0.64	0.66	3.72**	1.34	1.84*	1.02	3.3*	0.26
Avail. P	1.30	0.12	0.21	2.20*	0.98	2.20*	0.19	0.10	1.44	0.00	1.44	0.09	1.72*	0.88	1.72	1.58	1.90*	0.00	1.90*	0.00	1.90
Exch. Ca	1.44	0.13	1.23	1.81*	1.02	1.67	0.88	0.31	1.68*	0.72	1.37	0.96	1.31	0.83	1.22	1.00	0.23	0.72	1.08	0.38	0.85
Exch. Mg	0.09	1.05	1.60	0.74	0.53	0.36	2.10	3.14**	1.37	2.27*	0.67	0.91	3.32**	0.23	3.03**	4.40**	0.68	4.29**	1.26	1.08	0.96
Exch. K	0.40	1.31	0.91	0.85	1.68*	0.11	1.74*	1.41	1.23	2.66*	0.70	0.54	0.37	0.11	1.51	0.10	0.77	1.11	0.52	0.93	2.17
Exch. Na	0.27	2.67*	2.09*	3.3***	3.73**	3.76**	1.98*	1.75*	2.41*	0.28	2.75	0.14	1.34	2.1*	2.20*	0.96	1.41	1.58*	0.66	0.93	0.39
B S %	0.27	1.85*	0.93	1.17	0.67	0.77	0.97	0.95	0.54	0.00	0.26	2.14*	0.76	1.44	1.38	1.72*	1.41	1.47	0.62	0.54	0.11
CEC	0.96	0.23	0.60	1.62*	0.63	1.47*	1.01	0.76	1.98*	4.9***	1.50	0.73	1.50	0.76	1.39	2.20*	0.16	1.85*	1.16	0.39	0.96
Ex. acidity	0.93	1.96*	0.93	2.83	1.41	1.96*	5.11**	1.48*	0.93	3.54**	0.45	2.24*	0.66	0.66	0.00	2.78**	1.85*	2.24	1.41	0.66	1.66
pH ($CaCl_2$)	6.9***	2.24*	1.63	2.24*	0.58	3.25**	4.15**	0.73	5.1***	4.9***	3.7***	1.14	0.00	9.79	1.27	1.14	1.35	0.75	0.79	1.26	1.7*
pH (H_2o)	4.9***	2.56*	2.39*	2.56	3.24**	1.74*	1.70	3.58**	4.15	3.54**	4.0***	0.28	0.00	2.45	0.76	0.28	0.83	0.78	2.5**	0.76	1.77
ESP	0.71	0.93	0.62	0.12	0.90	0.36	1.70*	1.47*	0.75	1.81*	1.26	0.45	1.33	0.21	0.82	1.02	0.33	0.40	1.51*	0.71	0.82
SAR	0.55	1.75*	1.48	0.77	1.95*	1.46	1.99*	1.78*	1.21	2.14*	1.75*	0.33	1.34	0.03	0.60	1.00	0.40	0.23	1.62*	0.95	0.75

Locations; A =Giri-Wuna, B= Giyabiri, C= Ledi, D= Dadabiri, E= Paikon kore, F= Tungan Mallam Hassan, G= Gurfata and H= Dobi

Level of significance: * =0.1; ** = 0.05; *** = 0.01

4.2.1 Texture

For the cultivated plots, the mean sand content shows comparatively similar values over the different locations. It ranges from 60.5 percent in Ledi to 74 percent in Dadabiri farming communities. It is therefore, not surprising that ANOVA test did not reveal significantly different values amongst the different locations. The results obtained are not quite different when the cultivated plots where considered in pairs and the difference in sand content between the plots examined by using Student t-test, not quite a number of the pairs show significantly different values at 0.1, 0.05 or 0.01 confidence levels, with the exceptions of Giyabiri/Dadabiri, Giri-Wuna/Giyabiri, Giri-Wuna/Ledi, Ledi/Dadabiri, Dadabiri/Tungan Mallam Hassan and Dadabiri/Gurfata.

In comparing the mean value of the sand content for the treated plots with that of the control plots, the results show that the treated plots have consistently higher values, except for Gurfata which has lower value.

The silt content of the cultivated plots is considerably variable, with Ledi having the highest mean value of 22.5 percent. This is followed by Tungan Mallam Hassan 17.5 percent, Giyabiri 16.0 percent then Paikon kore and Gurfata 15.5 percent, Giri-Wuna and Dadabiri have the lower values of 13 percent and 9.5 percent respectively. Consequently the result of ANOVA reveals significantly different values amongst the various locations at 0.05 statistical levels.

For the results of the t-test, the differences are significant for Ledi/Paikon kore, Ledi/Gurfata, Dadabiri/Paikon Kore and Dadabiri/Tungan Mallam Hassan at the 0.1

statistical level, while those of Giyabiri/Dadabiri, Ledi/Dadabiri and Dadabiri/Gurfata show significant difference at least at the 0.05 level.

When the mean value of the silt content for the respective treated plots where compared with that of the control the results show some variations, with four farming communities of Giri-Wuna, Dadabiri, Tungan Mallam Hassan and Giyabiri having higher values, while three (Ledi, Paikon Kore and Gurfata) are having lower values, compared to the controls.

Unlike the sand fraction and similar to the silt fraction, the clay content of the cultivated plots show comparatively smaller amount compared to the respective control plots, Similar to the sand fraction, ANOVA did not reveal statistically significant different amongst the cultivated plots. Similarly, all the t-test values of the paired cultivated plots did not reveal significantly different value at any of the three statistical levels.

Thus, on the whole, the cultivated soils of the different locations showed comparatively higher sand content than the respective uncultivated long standing fallow plot. The more sandy texture of the cultivated plots may be attributed to disturbance by animal trampling and tillage operations which pulverize the soil and render the finer particles susceptible to removal in erosion (Leow and Smith, 1981; Lal, 1987; Yakubu 2004).

All soils in the area are sandy, being sandy loam. This is common feature in Nigerian savannas (Kowal and Kassan, 1976; Juo and Lal, 1977; Leow and Smith, 1981;

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Jaiyeoba, 1995; Mashi,1995. Such may be the reflection of felsic nature of the parent rock and/or the high surface erosion which removes fine soil particles. Eluviations can also be another important factor. Such textural class is however desirable for fertility of a soil, as it allows for the mechanical workability of the soils even at high moisture content and root penetration with less damage to soil structure, Raji et al (2005).

4.2.2 Bulk Density

The bulk density value of the cultivated lands is highest over Paikon kore and Tungan Mallam Hassan, with the value of 1.56g/cm^3. This is followed by Gurfata (1.50g/cm^3), Ledi (1.47g/cm^3), Giri-Wuna (1.44g/cm^3), and Giyabiri (1.29g/cm^3). The lowest value occurs in Dadabiri (1.28g/cm^3). The difference amongst the various locations by ANOVA is significant at 0.1 levels.

With respect to the t-test, eight pairs of the locations reveal statistically significant different values at either 0.01 or 0.05 levels. The pairs are Giri-Wuna/Gurfata, Giyabiri/Paikon kore, Giyabiri/Tungan Mallam Hassan, Dadabiri/Paikon kore, Dadabiri/Tungan Mallam Hassan, Dadabiri/Gurfata and Giri-Wuna/Giyabiri.

When the mean values of the respective cultivated plots were compared to the values of the controls, the results shows comparatively lower values for the latter. The higher values for the cultivated plots reflect presumably decrease in biological activities, poorer soil structure, low organic matter content and more sandy texture. Baring experimental error, the comparatively lower bulk density of the control plots are however expected and reflects greater biological activities which beside creating

porous condition results in greater addition of organic material to the soil (Brady, 2004).

Generally these values are high conforming with the observation of some researchers in Northern Nigeria (Inusa, 1990; Jaiyeoba, 1995; Abubakar, 1995; Yakubu, 2004).This high values is not critical to affect the proper function of the soils for a healthy plant production. For this textural class however, the ideal value should be less than 1.40 and the value that may affect root growth is 1.63 while values greater than 1.80 restrict root growth, Anikwe (2006), hence, the values ranging from 1.28 to 1.56g/cm^3 may not affect root growth.

4.2.3 Water Content

The mean soil water content is highest in Giri-Wuna (25 percent) and lowest in Tungan Mallam Hassan (10 percent). The values for the remaining locations are intermediate.

The differences amongst the various locations are significant at 0.1 levels, by analysis of variance. When the cultivated plots where considered in pairs, greater number of the paired plots where not statistically significant, except for the pairs of Giri-Wuna/Tungan Mallam Hassan, Giyabiri/Ledi, and Giyabiri/Tungan Mallam Hassan.

In Comparison to the control, the cultivated plots shows lower water content, except at Giri-wuna, Giyabiri,and Dadabiri were the values are higher.

The higher water content of the control plots is expected due to higher organic matter and clay content. But the greater values of the water content for the cultivated plots of Giri-Wuna, Giyabiri and Dadabiri is rather surprising but may be the reflection of the presence of rock fragments that reduces the available water capacity of the controls or the control plots here have shallower root barrier (Anikwe, 2006), which may reduce its water retention capacity.

4.2.4 Organic Matter (OM)

The soils OM content differs a little amongst the cultivated plots. The value ranges from 0.96 percent in Tungan Mallam Hassan to 1.90 percent in Dadabiri, the values for Gurfata, Paikon kore, Giri-Wuna, Ledi and Giyabiri lies in between the extreme values. ANOVA test confirm the observed variations, in that, the differences amongst the cultivated plots are statistically insignificant. When the plots where taken in pairs and the differences compared using *t-test*, the result showed that only two pairs are significantly different at 0.05 probability levels. The control plots have consistently comparatively higher content than the cultivated plots.

The organic matter content of the area is generally high. The higher OM content of the control plots reflect a high organic matter turn over and less disturbance through tillage and harvesting operations. The control plots with higher organic matter content are due to greater abundance of herbs and shrubs under growth (Jaiyeoba, 1988 and yakubu, 2004). This observed pattern of difference in OM between the cultivated and the control indicates some levels of mining of the soil nutrient base.

4.2.5 Total Nitrogen (TN)

The TN content of the cultivated plots did not show significantly different values amongst the different locations. The value ranges between 0.084 in Giyabiri and Dadabiri and 0.04 in Paikon kore. The controls show higher values with the exception of three farming communities of Paikon kore, Dadabiri and Tungan Mallam Hassan. The t-test shows no significant differences, between the pairs of the cultivated plots. The only exceptions are those between Ledi/Paikon kore, Dadabiri/Gurfata, Giyabiri/Paikon kore, Dadabiri/Paikon kore and Paikon kore/Gurfata.

The area generally, shows low level of TN content for both the control and the cultivated plots. The higher values for the control can be attributed to the greater relationships of the dense herbaceous undergrowth that releases or fix nitrogen and rapid humification. The generally low TN content of the area may be the result of loss of nitrogen through mineralization due to high temperature of the area. Leaching could also contribute, as leaching and volatilization is a common feature of most mineral soils (Brady, 1974 and Raji et al, 2005), and increased immobilization by plants.

4.2.6 Available Phosphorus (Avail. P)

Avail. P content show little variation over the cultivated plots of the different sites. The lowest value (9.41mg/g) occurs over Paikon kore and Gurfata. This is followed by 16.63mg/g in Tungan Mallam Hassan, 24.6mg/g in Giri-Wuna, 25.38mg/g in Ledi, 26.69mg/g in Dadabiri then 28.44mg/g in Giyabiri. ANOVA reveals no significant differences amongst the cultivated plots.

Using t-test, five pairs of Giri-Wuna/Paikon kore, Giri-Wuna/Gurfata, Ledi/Paikon kore, Paikon kore/Tungan Mallam Hassan and Tungan Mallam Hassan/Gurfata are significant at 0.1 levels, while the remaining pairs are not significant, in comparison with the controls, the cultivated plots shows lower values of the Avail. P than the control plots.

On the whole, the area shows moderate to high level of Avail. P, this could be the result of high enrichment by either green or farm yard manure and/or fertilizer application or through weathering of underlying parent material (Raji et al, 2005).

4.2.7 Exchangeable Calcium

The mean value of exch. Ca for the cultivated plots show some slight variations, with 9.45mol/kg (Ledi) as the highest value, then followed by 9.0 mol/kg (Giri-Wuna), 6.9 mol/kg (Giyabiri and Tungan Mallam Hassan), 6.6 mol/kg (Dadabiri), 5.9 mol/kg (Gurfata) and 5.6 mol/kg (Paikon kore) as the lowest. The control plots consistently show higher value than the cultivated plots. The highest value of 26.0 mol/kg over Dadabiri and the lowest value of 5.2 mol/kg over Gurfata.

The differences in the mean values amongst the cultivated plot is not statistically significant by ANOVA. Similarly, nearly all the pairs with exception of Giri-Wuna/Paikon kore, Giri-Wuna/Gurfata and Giyabiri/Paikon kore are not statistically different by t-test.

The calcium level in this area is generally high and could result from the lithology or rate of organic turn over (Anikwe, 2006).

4.2.8 Exchangeable Magnesium (Ex. Mg)

Exch. Mg show a significant variation amongst the cultivated plots with the highest value of 3.07 mol/kg in Dadabiri, then 2.79 mol/kg in Ledi, 2.64 mol/kg in Tungan Mallam Hassan, 2.24 mol/kg in Giri-Wuna, 2.20 mol/kg in Giyabiri, the lowest of 1.87 mol/kg in Paikon kore. The control plots are relatively higher in Exch. Mg with the highest value of 7.18 mol/kg in Dadabiri and lowest of 2.15 mol/kg in Gurfata.

By t-test most of the pairs of cultivated plots show statistically insignificant value, except for Giyabiri/Dadabiri, Ledi/Paikon kore, Ledi/Gurfata, Dadabiri/Gurfata and Dadbiri/Paikon kore.

4.2.9 Exchangeable Potassium

There is no marked variation in the Exchange Potassium content of the cultivated plots. The value ranged from 0.193 mol/kg in Giyabiri to 0.32 mol/kg in Tungan Mallam Hassan, consequently, ANOVA did not show significant difference amongst the various location. In comparison to the control plot, the values of the control plots show higher values for all locations except for Tungan Mallam Hassan.

Similar result was obtained in the t-test between pairs of locations, except for 4 pairs. These pairs are Giri-Wuna/Tungan Mallam Hassan, Giyabiri/Ledi, Giyabiri/Tungan Mallam Hassan and Tungam Mallam Hassan/Gurfata.

On the whole the area shows a medium level of Ex. K ranging between 0.19 and 0.32 mol/kg, and this could be mostly derived from the parent material.

4.2.10 Exchangeable Sodium

The highest Exch. Na. occurs in Giyabiri with the value of 0.31mol/kg and the lowest of 0.21mol/kg in Gurfata. The control plots show comparatively lower values in all the villages, except Paikon kore, Tungan Mallam Hassan and Gurfata .

ANOVA test reveals significant variations in the values amongst the treated plots at 0.01 probability level, so also the t-test for most pairs of plots. The entire study area has medium level of Exch. Na, which cold be from parent material of granitic origin.

The area has medium to high exchangeable cations which could possibly come from the greater immobilization by plants and animals as well as weathering and release of the elements into the soils (Fitzpatrick 1980). The lower values of the exchangeable cations for the cultivated plots compared to the control could be the result of greater losses through leaching and harvest over the arable lands than soils under natural vegetation (Jaiyeoba, 1995). There is however, optimum exchangeable cation that could encourage high fertility of the soils of the area, but the higher level over the control plots indicate some levels of soil nutrient mining on the cultivated plots.

4.2.11 Base Saturation

The percentage base saturation is highest in Ledi of 97 percent, followed by Paikon kore (97 percent), Gurfata (96 percent), Tungan Mallam Hassan (96 percent), Giyabiri (96 percent), Giri-Wuna (95 percent) and Dadabiri (94 percent). The differences amongst the various locations are not significant statistically.

The control plots have comparatively higher values than the cultivated plots, except Giyabiri and Gurfata. For the student t-test, majority of the pairs of plots did not show statistically significant different value except for Giri-Wuna/Ledi, Ledi/Dadabiri and Dadabiri/Paikon kore.

The percentage Base Saturation of soil over the study area is generally very high. The relatively lower values over the cultivated plots could be the result of leaching and absorption of ions by plants.

4.2.12 Cation Exchange Capacity (CEC)

The value of the CEC for the cultivated plots ranges from 8.37 meq/100g in Paikon kore to 13.09 meq/100g in Ledi. Those of Gurfata, Giyabiri, Tungan Mallam Hassan, Dadabiri and Giri-Wuna are intermediate. Comparing the mean values of the cultivated and the control plots reveals that the control plots have higher values, the differences amongst the cultivated plot by ANOVA is not statistically significant.

T-test analysis too, did not show significant difference between pairs of plots, the only exceptions are Giri-Wuna/Paikon kore, Giri-wuna/Gurfata, Giyabiri/Gurfata, Dadabiri/Paikon kore and Dadabiri/Gurfata.

Cultivated soils over the area generally, have low to moderate CEC. Those of the control are moderate to high level. These patterns may result from the relatively high organic matter contents and clay mineral which is predominantly of montemorilonite types (Fitzpatric, 1980). For fertility consideration this value of CEC is good for agricultural practices i.e. the nutrients retention capacity of these soils would be high.

According to Raji et al (2005) soils with CEC equal or greater than 8 cmol/kg would be suitable for intensive agriculture, therefore the soils of this area would be good for intensive agriculture.

4.2.13 Exchange Acidity

The value of the exchange acidity is lowest in Paikon kore (0.25) and highest in Dadabiri (0.55). The control plots have higher value than the cultivated plots, except Paikon kore, Gurfata and Giyabiri.

Consequently, the difference amongst the various sites is highly significant using ANOVA. When student's t-test was applied to the data, the result shows six of the pairs of plots to be significantly different. The pairs include Giri-Wuna/Gurfata, Giri-Wuna/Giyabiri, Giyabiri/Dadabiri, Ledi/Dadabiri, Dadabiri/Paikon kore, Dadabiri/Gurfata, and Dadabiri/Tungan Mallam Hassan.

The area show moderate level of exchange acidity with the control plots having lower exchange acidity compared to the cultivated plots. These differences of exchanged acidity in the control show presumably the higher vegetation cover, organic matter turn over and the lower leaching rate of the control plots compared to the cultivated plots. Hence, the level of the exchange acidity of the soils is within manageable limits for proper productivity of the soil.

4.2.14 pH

The soil pH reveals highly significant difference values amongst the various cultivated plots. The highest mean value occurs over Giri-Wuna (6.25 in $CaCl_2$ and

7.23 in distilled water). The lowest value occurs over Giyabiri (5.63 in $CaCl_2$ and 6.08 in distilled water).

Comparing the mean values of the pH of the cultivated plots with the control plots, shows the values of the controls in $CaCl_2$ to be higher than the cultivated with the exception of Paikon kore, but the pH values in distilled water shows the cultivated plots to be higher than the control except that of Tungan Mallam Hassan.

The T-test results also reveal significant differences between most of the pairs. On the whole, soils over the area are moderately acidic. This pattern is a reflection of the soil parent material, which are quartz-rich and the moderate leaching rate of the soils.

4.2.15 Percentage Exchangeable Sodium (ESP) and Sodium Adsorption Ratio (SAR)

The mean value for the ESP ranges from 2.11 percent in Ledi to 3.13 percent in Giyabiri. The differences amongst the cultivated plots by ANOVA are not significant statistically. Similarly the t-test result did not reveal significant different between most pairs of plots. The cultivated plots are consistently higher in ESP than the control plot. The mean value of SAR also shows comparatively similar values over the cultivated plots. The value ranges between 0.06 in ledi, Dadabiri, Tungan Mallam Hassan and Gurfata and 0.01 in Giri-Wuna and Giyabiri.

The overall values of both the ESP and SAR are low within the study area, this is due to low sodium in the exchange complex, high base saturation particularly of calcium and magnesium which displaces the sodium from the exchange site and leach them

out, high organic matter content of the area is another influencing factor of low ESP and SAR. This low level of ESP and SAR is important for high fertility of soils and hence, crop productivity (Raji et al 2005).

4.3 Farmers management Practices

4.3.1 Age and marital status

Table 4.3 Age and marital status of farmers

Age of farmers	Marital Status		Total (percentage)
	Married	Singles	
21 – 25	1 (2%)	13 (16%)	14 (18%)
26 – 30	6 (7%)	1 (2%)	7 (9%)
31 – 35	9 (11%)	1 (2%)	10 (13%)
36 – 40	17 (21%)	1 (2%)	18 (23%)
40 above	29 (35%)	0	29 (37%)
Total (percentage)	62 (79%)	16 (21%)	78 (100%)

Out of the sampled population, 20 percent fall within the age bracket of 21-25 years; out of this 2 percent are married while 16 percent are not married. Nine percent of the populations are within 26 – 30 years; with 7 percent are married and 2 percent single. Within the sampled population, 12 percent fall under 31-35 years, with 11 percent married and 2 percent single. Twenty four percent of the sampled populations are within the age of 36 – 40, with 21 percent married while 2 percent remain single. The age above 40 constitute about 35 percent of the sample population and are all married. The sampled populations therefore, have about 77 percent of the population being married and the remaining 23 percent are not married.

The highest percentage of the married population is above 40 years and the lowest percentage is within the age of 26 – 30 years, while the single population is highest within the age of 21 – 25 years with none in the age above 40 year.

4.3.2 Level of income of farmers

Table 4.4 Level of Annual Income in 1000 of Naira

Level of Income in thousand	Location								Total (percent)
	A	B	C	D	E	F	G	H	
>50	1	-	-	1	1	0	1	0	4 (4.9%)
50-100	1	3	2	2	2	2	2	1	15 (18.5%)
101-200	5	3	1	3	2	2	3	2	21 (25.9%)
<200	3	5	7	4	5	6	4	7	41 (50. 6%)

Locations; A =Giri-Wuna, B= Giyabiri, C= Ledi, D= Dadabiri, E= Paikon kore, F= Tungan Mallam Hassan, G= Gurfata and H= Dobi

Four point nine percent (4.9%) of the population in the study area have their level of income below N50,000 per annum. Eighteen point five percent generate income of between N50,000 to N100,000 per annum. The sampled population have about 25.9 percent with their income between N100,100 to N200,000 and 50.6 percent earned above N200,000 yearly.

Therefore, greater percentage earn more than 200,000 Naira per annum and few of the farmers earn below 50,000 Naira per annum.

4.3.3 Level of Education and Occupation

Greater percent of the population are predominantly farmers. Table 4.5 illustrates this:

Table 4.5 Level of Education and Occupation of farmers

	Occupation			
Level kjof Education	Farming	Civil Service	Others	Total (percentage)
Adult Education	10 (13.3%)	0		10 (13.3%)
Primary	10 (13.3%)	0	0	10 (13.3%)
Post Primary	18 (24.0%)	0	5 (6.7%)	23 (30.7%)
Post Secondary	2 (2.7%)	12 (16.0%)	0	14 (18.7%)
Non Western education	18 (24.0%)	0	0	18 (24.0%)
Total	58 (77.3%)	12 (16.0%)	5(6.7%)	75 (100)

Overwhelming proportion of the respondents indicated farming as their primary occupation. Out of 77.3 percent, 24 percent and 2.7 percent have attended post primary and post secondary education respectively, 13.3 percent and 13.3 percent have informal and primary education while 24 percent have not acquired any form of training. Only 16 percent of the respondents farmers are primarily civil servant and have all acquired post secondary training. The remaining 6.7 percent are still schooling at post primary level.

4.3.4 Number and size of plots

Table 4.6 **Number and size of plots**

Number of plots	Sizes of plots				total
	<3	3-5	5-8	8<	
1	-	1 (1.3%)	-	-	1 (1.3%)
2	-	1(1.3%)	2 (2.6%)	1(1.3%)	4 (5.2%)
3	-	-	9 (11.7%)	5 (6.5%)	14 (18.2%)
4	-	-	1 (1.3%)	36 (46.8%)	37 (48.1%)
5	-	-	-	12 (15.5%)	12 (15.5%)
6	-	-	-	9(11.7%)	9 (11.7%)
Total	-	2 (2.6%)	12 (15.6%)	63(81.8%)	77 (100%)

Greater number of the respondents owns about four plots located in different farming sites belonging to their communities. In 48.1 percent of this category 46.8 percent have more than 8 hectares with 1.3 percent having between 5-8 hectares when the 4 plots are put together. Out of the respondents 18.2 percent owns about 3 plots with 11.7 percent covering between 5-8 hectares and 6.5 percent covering more than 8 hectares. About 15.5 percent owns 5 plots in different locations, when these plots are put together they could cover more than 8 hectares. Eleven point seven percent owns 6 plots in different places which are more than 8 hectares when put together. Among the respondents 5.2 percent owns only 2 plots in different locations, out of which 2.6 percent covers between 5-8 hectares, 1.3 percent cover more than 8 hectares and 1.3 percent covers between 3-5 hectares. But only 1.3 percent owns just a plot which is between 3-5 hectares.

However, most of the respondents hold more than 8 hectares in different locations; constituting 81.8 percent, 15.6 percent are in possession of between 5-8 hectares while only 2.6 percent have between 3-5 hectares.

4.3.5 Types of crops grown

Table 4.7 Crops grown in the study area

Types of crops	Locations							
	A	B	C	D	E	F	G	H
Yam	10	10	10	9	10	11	9	11
Guinea corn	10	10	10	9	10	11	9	11
Maize	10	10	10	9	10	11	9	11
Groundnut	3	0	0	0	2	0	0	2
Millet	1	0	0	0	0	8	0	0
Garden egg	7	0	0	0	5	0	0	6
Melon	0	10	10	9	9	0	9	10
Beans	3	0	1	0	1	10	0	1
Cowpea	6	4	4	5	1	3	5	9
Ben seed	1	2	4	3	2	2	2	2
Cassava	0	2	0	2	0	10	2	1
Rice	2	4	1	2	1	3	1	1
Soy bean	0	0	0	0	1	4	0	1

Locations;A =Giri-Wuna, B= Giyabiri, C= Ledi, D= Dadabiri, E= Paikon kore, F= Tungan Mallam Hassan, G= Gurfata and H= Dobi

All those who responded to this section grows yams, guinea corn and maize, which are the major crops grown within the study area. Groundnut is grown in some few areas within the study area, mostly in Giri, Paikon kore and Dobi. Some of the sampled population grows millet, commonly found in Giri and Tungan Mallam Hassan, but Marjoly grown in Tungan Mallam Hassan. Garden egg is grown mainly in Giri, Paikon kore and Dobi.

Another important crop grown in this area is melon, grown mostly in all the study area with exception of Giri and Tungan Mallam Hassan. Beans is also grown by some of the population in the area except in 3 farming communities of Giyabiri, Dadabiri

and Gurfata were no farmers indicated this. While cowpea and Ben seed are grown all over the study area. Cassava is mostly cultivated in Tungan Mallam Hassan other places include Giyabiri, Dadabiri, Gurfata and Dobi. Rice is grown all over the farming communities but dominantly in Giyabiri.

The major crops grown in the study areas are yams, guinea corn and maize. Groundnut is grown in mixed composition with the major crops particularly guinea corn and maize and these they said is an introduction by farmers from other parts of the country. Millet that is commonly grown in Tungan Mallam Hassan is a crop grown by Fulani settlers that are found in this community. Garden egg grown in some of the communities is a cash crop grown in the early stage of the rainy season to complement the income of the farmers. Melon is grown in almost all the farming communities, Melons are grown in rotation with the major grain crops, for fertility improvement and as cash crop. Beans and cowpea found all over the farming communities are grown to improve the soil fertility and health and for food. Beniseed are grown by spreading the seed over a newly produced hips of yams, this practice help to prevent surface wash by rain action on the lips and the tendrils are also used to mulch the yam during planting.

Cassava is another important tuber crop grown in some of the communities, particularly in Tungan Mallam Hassan, they are cultivated in rotation with the major grain to improve the fertility of the soil and for food, as well as source of revenue to the farmers. Rice is another crop cultivated scatted all over the farming community mostly in swampy areas and other forms of wetlands within the area, apart from being cash and food crops, the leaves are used to mulch yam during planting. Soya beans

are grown in mix with the major grain crops to improve the soil fertility and for food and cash crops.

4.3.6 Management of crop residue

Table 4.8 Management of crop residue

Location	Burn them	Use as feed	Left in farm
Giri-Wuna	3	1	6
Giyabiri	10	0	10
Ledi	8	0	10
Dadabiri	7	1	9
Paikon Kore	4	1	9
Tungan Mallam Hassan	0	7	5
Gurfata	8	0	9
Dobi	8	1	10

Overwhelming population of the sampled farmers' burn their crop residue, particularly during land preparation and after harvest, but in Tungan Mallam Hassan, crop residues are not burnt as most of the crop residues are use as animal feeds. Although 11 of the population uses crop reside as feeds out of which 7 are in Tungan Mallam Hassan. Crop residue are also left in the farm after harvest which serve as pasture for the herdsmen and the remaining that are not grazed are left on the soil to decomposed. And this practice is found in all the farming communities with Tungan Mallam Hassan having the least of such practices.

However, some numbers (62 farmers) of the population chooses the option of both burning the crop residue and leaving the crop residue in the farm as pasture and to decompose. Burning during land preparation is a normal practice in clearing of land while such practice after harvest is to reduce the extent of animal trampling the soil during pasturing and thereby reducing the soil quality. But in Tungan Mallam Hassan

where mixed farming is practiced, burning the crop residue is never an option, as they are used as animal feeds and the animal dumps in turn are used as manure to improve the soil quality.

In most places within the study area, the farmers abandon the farm after harvest only to show up during land preparation. By this, the crop residue serve as pasture for nomadic herdsmen and the decomposable ones are arranged to be buried in the soil, to decompose and serve as manure while those that cannot decompose within the farming season are burnt.

4.3.7 Perception on Soil Fertility

Table 4.9 Farmers perception of soil fertility in there Area

Location	Increasing	Decreasing	Unchanged	Total
Giri-Wuna	-	9	-	9 (13.8%)
Giyabiri	-	9	-	9 (13.8%)
Ledi	-	6	2	8 (12.3%)
Dadabiri	-	7	-	7 (10.8%)
Paikon Kore	1	4	-	5 (7.7%)
Tungan Mallam Hassan	-	9	-	9 (13.8%)
Gurfata	-	10	-	10 (15.4%)
Dobi	-	8	-	8 (12.3%)
Total (Percent)	1 (2%)	62 (95%)	2 (3%)	65 (100%)

In soil fertility assessment, 95 percent of those who respond to this section among the sampled population believe that the soil fertility of the area is decreasing with years of cultivation. Four percent of the population believes that the soil fertility status is not

changing with cultivation while one percent believes that it increases with year of cultivation.

The farmers identified the fertility status of their soils using some indicating features like decreasing yield, stunted growth of crops, late growth and maturity and emergence of striga in the farm. Fifty nine farmers for instance identifies decrease in soil fertility through decrease yield of their crops, 6 farmers through stunted growth, 34 respondents through late growth and maturity while 46 farmers through the emergence of striga.

However, most of the farmers identify fertility status of their soils by more than one feature. That is the combination of either two or all of decreasing yield, late growth and maturity, as well as emergence of striga. Most of the farmers comprising of about 92 percent agreed that continuous cultivation is the crucial factor responsible for soil fertility decrease. Four percent attributed the decreasing soil fertility to grazing by herdsmen and one percent said it was due to bad management, and one percent turns out to be odd, who believes that the soil fertility status is increasing due to good management practices.

Most of the farmers in the area believe that soil fertility in the area is decreasing due to continuous cultivation.

4.3.8 Soil/Land degradation assessment

Table 4.10 Soil and Land degradation

locations	Structural degradation (Loose of structure)	Sheet erosion	Rill erosion	Gully erosion
Giri-Wuna	10	-	-	-
Giyabiri	10	-	-	-
Ledi	10	-	-	-
Dadabiri	9	-	-	-
Paikon Kore	10	-	-	1
Tungan Mallam Hassan	9	7	3	2
Gurfata	10	-	-	-
Dobi	11	-	-	-

Greater number of the sampled farmers (79 farmers) identifies loose of structure as the prominent type of soil and land degradation in the area. While 13 farmers identifies sheet, rill and gully erosions alongside loose of structure that are mostly in Tungan Mallam Hassan.

The severity of degradation is mild according to about 7 percent of the population while 84 percent believe it is moderate with 9 percent who chooses both mild and moderate scale.

However, the prominent soil/land degradation in the study area is structural degradation which is at moderate scale. But in Tungan Mallam Hassan, apart from surface loose, sheet, rills and gully erosion all at moderate and mild scale respectively were identified by the farmers.

4.3.9 Perception on the Causes of Soil andLand Degradation

Table 4.11 Causes of Soil Degradation in Gwagwalada

locations	Ridging pattern	Grazing	Burning	Continuous cultivation
Giri-Wuna	2	1	-	6
Giyabiri	-	-	-	10
Ledi	2	-	1	8
Dadabiri	-	-	-	9
Paikon Kore	-	-	-	10
Tungan Mallam Hassan	10	10	-	10
Gurfata	-	-	-	9
Dobi	-	-	-	11

The soil degradation is believed to be caused by continuous cultivation by all the respondents, 14 of the sampled population believed it is caused by the ridging pattern,10 of which are from Tungan Mallam Hassan, 2 from Giri and 2 from Ledi. Eleven of the farmers believe it is caused by burning, 10 in Tungan Mallam Hassan and 1 in Giri. While 1 farmer in Ledi believes it caused by burning, however, all the respondents in Tungan Mallam Hassan selected 3 options of ridging pattern, grazing and continuous cultivation.

Loose of structure of this farming environment is attributed to continuous cultivation, while sheet, rills and gully erosion are attributed to ridging pattern and grazing by animals.

4.41 Soil conservation practices

Table 4.12 soil conservation methods

Location	Mixed cropping	Mixed farming	Bush fallowing	Crop rotation	Mulching	Chemical fertilizer	Organic manure	Bush burning	Ridging pattern	kushere
Giri-Wuna	9	-	9	9	9	9	9	9	9	9
Giyabiri	10	-	10	10	10	10	10	10	10	9
Ledi	10	-	10	10	10	10	10	10	10	9
Dadabiri	9	-	9	9	9	9	9	9	9	9
Paikon Kore	10	1	10	10	10	10	10	10	10	6
Tungan Mallam Hassan	10	5	10	10	10	10	10	10	10	4
Gurfata	10	-	10	10	10	10	10	10	10	9
Dobi	11	-	11	11	11	11	11	11	11	10

The soil conservation practices of the farmers in this area include mixed cropping; bush fallowing, crop rotation, mulching, and application of chemical fertilizer and organic manure, bush burning, making of ridges in form of ridges and hips for yams, and "kushere". All these practices were described by most of the sampled population in the various farming communities.

Mixed cropping is practiced with crops like guinea corn, maize, cowpea, beans and Soya beans planted together in the same plot of land. In some cases, melon is planted earlier to be harvested at the early stage of the guinea corn growth while the residues of the melon and other grasses are buried in the ridges to serve as manure. Mixed farming is also a conservation method identified by some 6 farmers of the sampled population which is peculiar to Tungan Mallam Hasan where there are number of Hausa/Fulani settlers. They farm crops and rear animals like cattle, sheep, and goats. They use crop residue like strews, groundnuts and beans tendrils as feeds for animals while the animal dump are used as manure to other crops.

Bush fallowing is another important soil conservation method that is widely used in these communities and this is made possible with the availability of farmland in the areas with most of the farmers having more than 3 plots of farm land located in different places. Crop rotation is pointed out to be another soil conservation method adapted by the farmers. Crops like yam and cassava are followed by grain crops. And nitrogen fixing crops are either planted in mixed with the grain crops or are followed by the grain crops.

Mulching is commonly used on yam hips only. To protect the yams (seeds) from intense heat of the dry summer sun. The materials used are mostly grasses, leaves, strew and tendrils of crops.

Chemical fertilizes and manures are generally used in the area. This is to augment for nutrient depletion in the area. The commonly used fertilizers are NPK and urea. The use of chemical fertilizer they said is to supplement quick nutrients for the crop while manure helps to conserve the soil quality.

"Kushere" as a method of weed control in the farm also helps in soil conservation. In "Kushere" when weed began to grow in the farm, i.e. two to three weeks of the crop planting. Weeds are drawn from the ridges, turned and buried in the inter row using hoes; after two to three weeks, depending on the rate of weeds growth, the weeds are drawn from the mini-ridge made in the inter row, turned and buried in the main ridges again continuously until the crops are fully matured. This practice is identified by about 79 percent of farmers in the areas as important practices.

4.4 Discussion

4.4.1 Soil Fertility Status

From the foregoing analysis, it can be seen that there are some levels of deterioration of soil properties under cultivated plots in the study area. The soils show no significant difference in sand and clay content amongst the different locations while in that of silt, there is significant difference amongst the cultivated farms. This is probably due to difference in lithology of the area. The soil of the area is however sandy loam with the cultivated having more of the sand and less clay content than the

control. This has however reveals more eluviations and or surface wash in the cultivated plots and hence, loose soil aggregation.

Both bulk density and water content show significant difference at 0.1 levels. This is an indication of different rate of deterioration of the soils of the different farming communities due to soil compaction. This could be due to trampling by animals and/or level of farm intensification, for instance higher values in Tungan Mallam Hassan (with considerable number of herdsmen) and Paikon Kore. These places are also very close to dense populated areas of Zuba and Gwagwalada towns respectively, hence soils of these farming communities would be under intense cultivation than those of other farming communities. This is also accompanied by lower organic matter content in these areas, although no significant difference in the content of organic matter among the farming communities.

Most of the chemical properties of the soils show no significant difference amongst the farming communities. This shows almost uniform rate of deterioration in the cultivated plots of the area. The relatively higher values of most of the chemical properties and lower values of the exchange acidity, pH, ESP, and SAR of the control plots shows that the cultivated plots have being deteriorated relative to the control plot of the area. The impetuses have been set for the leaching and replacement of the positive ions by the negative ions within the exchange complex thereby increasing the acidity and sodification level of the soils gradually in the cultivated plots.

The deterioration of the soil condition under cultivation relative to the long standing fallowed lands, are essentially the reduction in activities of soil organism and the

interruption of the biogeochemical cycling of the matter. Other factors contributing towards degradation are mixing invasion and homogenization process which is necessitated from several soil management operations. In the control plots, which represent a natural undisturbed ecosystem, there is a close cycle of nutrient between vegetation and soils nutrients which have been taken up from the soils are returned to the surfaces of the soil in form of litter and through leachate of leaves of many species. This is acted upon by fungi, termites; humus confers upon the top soils (Williams and Joseph, 1970). Under such condition, there is cohabitation of low number of a wide variety of species with different needs and demands. The maximization of diversity of species occurring in a low amount extracts minimum energy requirement from the soil, resulting in low rate of disturbance within the ecosystem (Turnbill, 1969).

Land coverage and cropping destroy this balance and introduces a narrow range of nutrients hungry plants in high density. This results in increasing energy requirements and therefore the destabilization of the ecosystem. Nutrients are extracted from the soil by heavy feeding crops or plants but instead of allowing these to return to the soil by way of natural decomposition of organic materials, they enter food chains outside the farm locality, thus contributing to loss of the materials in the soil system (Yakubu, 2004).

Besides the obstruction of the biochemical cycle, subjecting a virgin soil to tillage operation, initiates what could be described as breaking of the 'soil body'. This is the result of the loose of soils adhesives properties in particular clays, organic matter and microbial products and the force exerted by tillage implements. The pulverization of

the soil by this process makes the soil materials more susceptible to removal by running water and wind (Yakubu, 2004).

According to Bello (1973), Faniran and Jeje (1983) and Stocking (1995), whenever the soil vegetative cover is removed for any reason, can give rise to formation of surface cap and reduce the rate of infiltration, which would result into a sheet flow. And there would be selective removal of the finer particles and may constitute a major reason for the degradation of soil physical properties as described by Jeje (1982).

Overgrazing exposes the surface directly to the weather elements, where several animals are concentrated in a given restricted area, there is a tendency for accelerated soil compaction as the trampling effects of livestock tend to destroy the soil structure. This also has a profound effect in the study area that affect even the control plots which give rise to high bulk density values in the study area.

4.4.2 Farmers Management Practices

The major occupation of the people in the communities of Giri, Giyabiri, Ledi, Paikon Kore, Dadabin Gurfata, Tungan Mallam Hassan and Dobi is farming. Most of the population below the age of 26 are single and are dominantly attending Post Primary Education with lower income level, i.e mostly dependant while the bulk of the successful farmers (higher income level) are above 40 years of age. Mostly does not attend any form of western education, even though some little percentage who attended post-secondary combines farming and civil service.

Most of the farmers own more than three plots of land located in different places, hence, large expanse of land of more than eight hectares. The major crops grown in the area are guinea corn, maize, and yams. Other crops are also grown either mixed or in rotation with the major crops.

Most of the crop residues are burnt during land preparation and some are left in the farm as pasture, in communities that practice mixed farming and the residues are used as animal feeds. The soil fertility are according to the farmers reducing with years of cultivation of the lands and the features that inform them of this are decreasing yield, late grown and maturity as well as emergence of striga in the farm, the reason for this being principally continuous cultivation. The most prominent soil/land degradation is loose soil aggregation in most of the communities and sheet erosion in Tungan Mallam Hassan, all at moderate rate with causative factors of continuous cultivation for loose soil aggregation while rigging pattern and overgrazing for sheet erosion.

The soil conservation methods practice by the farmers include mixed cropping, mixed farming in Tungan Mallam Hassan, bush fallowing, crop rotation, mulching on yams only, chemical fertilizers, organic manure, bush burning, during land preparation, ridging in form if raw and hips and kushere.

The farmers suggested bush fallowing, use of fertilizers, the use of manure in the plain and planting of trees and grasses in areas of Zuba dissected terrain. The lower number of younger age farmers (the youth) has a far reaching implications, the youth which form the active population has abandon this occupation for non-agricultural activities in the towns while the aged and the non literature population (above 40

years) are the dominant in the farming activities with consequence of conservatisms and superstitious in their belief, although, they have acquired experience of the long time practice which could result in the identification and adaptation of the best practices.

There is decrease in the soil fertility with years of cultivation as depicted by the farmers. This is as a result of nutrient removal by the crops. To improve this, the farmers adapt various management practices, for instance mixed cropping where the farmer grow some suite of nitrogen producing crops such as groundnut, beans, cowpea, and Soya beans between maize or guinea corn. These legumes do not only fix nitrogen to the soil but creep on the ground to provide cover against incidence of solar radiation on the soil and shield the soil from the rain impact. By this, it increases microbial activities in the soil, improves the structure, increases the rate of infiltration, thereby reducing the rate of surface wash. There is also increase in the rate of decomposition of the litter from the cover crops of their leaves and tendrils. Melon which is also a cover crop with same advantage is planted in more of rotation with guinea corn than in mixed. Because melon has a short maturity period, it is planted as soon as rain starts. As it get close to its maturity period, guinea corn is planted, though at that stage, it retards the growth of guinea corn, but as soon as the melon is harvested and the farm is weed up using 'kushere', the guinea corn then grows rapidly.

Beniseed is spread on a new hips of yam to protect it from rain impact and surface wash before the next growing season. Yams and cassava are normally cultivated in rotation with maize and guinea corn. Yams are normally cultivated on a virgin land.

The hips of yam would serve as plough that would break up the land for root penetration of the grain crops. In Tungan Mallam Hassan, cassava is planted in a weak soil for two years, and then it is followed by either of the grain crops. Rice are farmed mainly on swamps and wet lands. Kushere could be an important practice that will help in adding organic matter and nutrient from the decomposed weeds growing in the farm. This will in turn improve the soil quality.

CHAPTER FIVE

SUMMARY AND CONCLUSION

5.1 Summery

5.1.1 Soil Fertility Status

The study asses the fertility status of the soils on Gwagwalada area council and the farmers' management practices. It looks at those factors that are crucial to fertility and soil quality for effective agricultural practices in the area. It also considered the farmers perception on the fertility and soil degradation as well as their observe causes and their management practices. The factors of soil with its many tangible physical, chemical and biological characteristics are one of the primary criteria for evaluating soil fertility and its quality.

Topography is extremely important in agriculture for it influences the choice of labour requirements, the drainage requirements, the erosion hazards, the range of possible crops, the cost of land development and the possible size and shape of the field. Within this study area, there are two distinct topographies that influence the agriculture in the area. The extensive Iku-Gurara plain comprising of the farming communities of Giri-Wuna, Giyabiri, Ledi, Dadabiri, Paikon Kore, Gurfata and Dobi, farming here is not restricted by topographic factors, the area is not susceptible to erosion, encourage the production of varieties of crops. The relief favours high infiltration rate, hence high moisture capacity. Zuba dissected terrain on the other hand where Tungan Mallam Hassan lies, has many restrictions to farming due to uneven and rugged relief. The area is susceptible to erosion; reduce infiltration rate and hence high bulk density, low moisture content and organic matter.

Texture is one of the most basic soil characteristics for consideration in soil appraisal. It influences such complex soil qualities as infiltration, moisture and nutrient retention, drainage, tilth and susceptibility to erosion. It effects on these qualities may be modified by soil structure, nature of clay minerals, and organic matter and lime content. Satisfactory textural diagnostic criteria for soil rating are difficult (Malgwi 2006). However, the textural class for the soils of the study area is satisfactory for high productivity of plants (sandy loam). With the high organic matter in the soil and calcium complex will help in multiplying the infiltration, nutrient and moisture retention, the drainage tilth, and reduces susceptibility to erosion.

Bulk density of highly productive soils usually ranges from 1.0 – 1.5 (medium to fine texture) and 1.1 – 6.5 (coarse texture). The soils of this area could be said to be medium to coarse texture (sandy loam) and their bulk densities ranges between 1.28 and 1.56. Therefore, the bulk densities of the areas would support healthy growth of crops.

The degree of acidity or alkalinity of a soil expresses as a pH value is defined as the 'negative logarithm of the hydrogen ion activity''. The pH condition favouring high soil fertility is between 5.6 – 6.5 and 5 – 8.0, but varies with crops. Beside the soil reaction, pH is an indication of other conditions in a soil, example

(i) Values of soil pH in 0.01 $CaCl_2$ less than 4.8 indicate neutral salt exchange activity in most soils. This is due to monometric Al ions.

(ii) Calcerous non-sodic soils have pH in 0.01M of about 7.5 while sodic soils are usually above 7.5.

(iii) pH values of water saturated soil paste less than 7.6 usually indicate the presence of alkaline-earth carbonate.

(iv) pH (paste) value above 8.5 commonly indicate an exchangeable Na percentage may or may not exceed 15.

Hence, the soils of the study area which has their pH in $CaCl_2$ ranging between 5.63 and 6.25 with that of distilled water ranging from 6.08 to 7.13 are favourable for high fertility. The soils indicates no neutral salt exchangeable (no monometric Al ions). The soils are calcareous non-sodic soils and there is presence of alkaline-earth carbonate.

Soils of inherently high productivity usually have exchange complex dominated by Ca and Mg and containing only minor amount of K and Na. highly productive soils are usually at least 50 percent base saturated with a preponderance of Ca. If other factors are favourable, a level of 6meg/100g soil of exchangeable Ca is generally sufficient to ensure crop production. Calcium imbalance may also have detrimental effect on soil structure and thus upon infiltration capacity, permeability, soil tilth and susceptibility to erosion.

Within the study area, there is high level of Ca and Mg, but medium level of K and low level of Na, and the area has generally high base saturation of more than 50 percent with preponderance of Ca. Therefore, the soils of the area are highly productive (fertile) with sufficient Ca to ensure crop production. And balanced to improve infiltration capacity, permeability, and soil tilth and reduce its susceptibility to erosion.

In evaluating soils, interest in CEC values is two fold, as a measure of potential productivity in term of the capacity of the soil to retain and supply plant nutrients and as a clue to the nature of the clay Minerals present, CEC values exceeding 8 or 10 meq/100mg of soil in the upper 30cm usually reflect soil capable of satisfactory crop production if other factors are favourable. The CEC for the study area ranges between 8.37 and 13.08 meg/100g of soils, hence, the soil is capable of satisfactory crop production if other factors are favourable.

ESP or milli equivalent of exchangeable Na are usually for indicators of the structural stability of soils because Na is a dispersing agent in soil. In general, physical properties become increasingly unfavourable with increasing level of Exch. Na, but at a given ESP, physical properties are usually poorer in soils. Although different crops have different level of tolerance to ESP, but the ideal limit of ESP for high production is 15 percent when other factors are favourable. A recent method of evaluating level of Na in soils is the sodium Adsorption Ration (SAR); is a value that accounts for the removal of Ca and Mg by their precipitation with bicarbonate and carbonate ions in solution, giving a truer picture of the sodicity of the soil. The ideal limit of sodicity using SAR is 13.

The soils of the study area have ESP varying from 2.1 percent to 3.1 percent while SAR ranges between 0.05 and 0.081, this level of ESP and SAR are quite low and therefore, favourable for high crop production.

Soil Organic Matter according to Natural Resource Conservation Service (1996) includes plants and animals remain in various stages of decomposition, cells and

tissues of soil organisms and substances from plant roots and soil microbes. Well decomposed organic matters forms humus, a dark brown porous, spongy material that has a pleasant smell. In most soils, the organic matter accounts for less than 5 percent of the volume. Organic matter is however essential for the following purposes.

(i) Provides a carbon and energy sources for soil microbes.

(ii) Stabilizes and holds soils particles together, thus reducing the hazards of erosion.

(iii) Aids the growth of crops by improving the soils ability to store and transmit air and water.

(iv) Stores and supplies such nutrients as nitrogen, phosphorus and sulfur, which are needed for the growth of plants and soil organisms.

(v) Retain nutrients by providing cation – exchange and anion exchange capacities.

(vi) Maintains soil in an uncompacted condition which lowers bulk density.

(vii) Reduces the negative environmental effects of pesticides, heavy metals and many other pollutants. Soil organic matter also improves tilth in the surface horizon, reduces crusting, increases the rate of water infiltration, reduces run off and facilitates penetration of plant roots.

The organic matter condition required for high soil fertility is high level. And the organic matter for the whole of the farming communities is high and can perform the above mentioned functions except for Tungan Mallam Hassan which has low organic matter. Plants require nitrogen, potassium and phosphorus (NPK) in a high level to grow, without these elements; there will be deficiencies in plant growth, although different species and sub-species may have very different requirement even in the

same community (James *et al.,* 1996). Nitrogen is the common limiting factor in most ecosystems. Within the study area, the nitrogen level is generally low while phosphorus is low in Paikon Kore and Gurfata and medium in Tungan Mallam Hassan and high in the remaining farming communities. Potassium on the other hand is generally at medium level within the study area.

Therefore, the area is deficient in nitrogen, with moderate potassium and adequate phosphorus in most of the farming communities.

The soils of the area have high level of fertility with all the fertility parameters being either moderate to high with only nitrogen occurring at a low level. Even though the areas are generally fertile, the areas differ in productivity potentials. Tungan Mallam Hassan on Zuba dissected terrain has the lowest fertility status. This could be attributable to the loss of organic matter and essential nutrients through erosion; the process that selectively detaches and transport particles on the soil surface that have highest content of organic matter that helps in improving soil fertility and quality, Paikon Kore and Gurfata are the next to Tungan Mallam Hassan. All these areas have higher level of intensification of farming due to proximity to the densely populated areas of Gwagalada town and Zuba while Dadabiri and Giyabiri are the most fertile areas then followed by Giri –Wuna.

5.1.2 Soil Management Practices

Much of the farming population consist of aged people mostly constituting those above 36 years of age who have not acquire formal education. Most of which has their

income level above N100, 000 per annum. And most of the youths are either studying or engaged in non agricultural activities.

Most of the farmers own more than three plots of not less that eight hectares of land in different places. Though owns large expanse of land but utilized in the practice of bush fallowing and crop rotation. The major types of crops grown in these communities are yam, guinea corn and maize, with melon, cowpea, beans and Soya beans in mixed or rotation. Other crops include beniseed, millet, garden egg, cassava and rice in swampy areas.

The major form of soil/land degradation is loose soil aggregation at a moderate level which is induced by continuous cultivation. And another form of degradation of the land is erosion; sheet erosion at moderate level, while rills and gully at mild level confined to the area of Zuba dissected terrain caused by ridging pattern and overgrazing in addition to continuous cultivation. The soil fertility status in the area is generally decreasing as noticed by the farmers, with years of cultivation.

The basic system of farming in the area is mixed cropping on Iku-gurara plain and mixed farming on Zuba dissected terrain. Ridges and hips are the major form of seed bed operation for cereal/legumes and yams respectively. Bush fallowing and crop rotation are important soil conservation method in the areas. The farmers also use manure and chemical fertilizer to improve the fertility of their soils.

"Kushere'' is another soil conservation and weed control practice within the study area. This helps in increasing the organic matter content in the soils by burying and

decomposition of premature weeds into the soil. This process involves tilling the soil, burying the plants, decomposition of the weeds and mixing of the decomposed weeds in the soil. These processes have the following impact on the soil according to Anikwe (2006). When the soil is tilled, organic matter is decomposed faster because of the changes in water, aeration, and temperature condition. Mixing of the residue into the soil generally destroys fungal hyphae and favours the growth of bacteria, since bacteria hold less carbon as carbon dioxide. The net result is loss of organic matter from the soil. But when they are turned and left on the surface of the soil, primary decomposition is by arthropod shredding and fungal decomposition takes place. The hyphae of fungi can extend from below the soil surface to the surface liter and connect the nitrogen in the soil to the carbon in the soil. Fungi maintain a high C:N ratio and hold carbon in the soil. The net result is towards building the carbon and organic matter level of the soil. These processes also hold when crop residues are left in the farm to decay. In this farming system, that return residue, micro–organisms are important. It helps to manage the soil to increase their diversity and numbers (National Resources Conservation Service, 1996).

The use of cover crop and crop rotation has its advantage as mentioned earlier, but the type of crops that are used as cover crop or in rotation can affect the mix of organisms that are in the soil. They can assist in the control of plant pests or serve as hosts to increase the number of pests. Different species and cultivars of crop may have different effects on pests. However, the organism and their relation to the crop are presently not clearly understood (Anikwe, 2006) and so remain a best practice.

Burning remains an important and easier method of land clearance in the area. And have the effect of decreasing the supply of organic materials, grazing also have similar effects in addition to compaction of the soils. The soil cultivation method in this area is a compatible tillage system that physically maintains soil organism habitat and biological diversity in crop production since according to Anikwe, (2006). No till, ridge tillage and strip tillage favours high production of crops.

The best practices in this study area, therefore includes mixed cropping, and crop rotation, mulching, (on yams only), mixed farming in Zuba dissected terrain, the use of chemical and organic fertilizers, the tillage practices and most importantly bush fallowing and Kushere.

5.3 Management Practices and Soil Fertility Status

The land ownership in the area (farm plots located in different places) is that which encourage the practice of bush fallowing and crop rotation. These practices are made possible due to the present level of the population of the area and land availability, but as the population grows, these practices may prove difficult due to land shortage, attention must therefore, be shift from these practices to other soil management practices. However, crop rotation and bush fallowing are good practices particularly on the fragile soils of the savanna, though may seem primitive but proven a good way to manage acrisols (i.e. soils of the study area) Soil Survey Staff (1975).

Burning is also a practice within the study area that helps in mobilizing and making nutrients available within the few months of the burning. Therefore, early planting of cereal crops that requires high input of fertilizer (i.e. maize) in the area is a good

practice. Nitrogen deficiency in the area is supplemented with legumes (nitrogen fixing crops) in mixed cropping, even though it is not enough to supplement for the high nitrogen intake of the cereal crops.

The soil fertility status being high is attributable to the farmers' management practices that enhance nutrient cycling and organic matter incorporation in the soils i.e. bush fallowing, crop rotation, manure application and "kushere". Bush fallowing for instance, help in restoration of a deteriorated soil, with the timing of when to fallow a land (base on decreasing yield and emergence of striga on the soil) which is a good indication for identifying deteriorating soil, and the period of fallowing normally six years and above enough for soil resilience processes. Mix cropping of legumes and cereal, apart from the beneficial effect the legumes has of fixing nitrogen in the soils for grain crops, it mulch the soils from the deteriorating effects of rain action and solar heating. "Kushere" and manure application improves the soils quality through their effects of adding organic matter to the soils. The farmers practices of allowing the crop residue on the farm plots after harvest attracts herdsmen with their herds to pasture in the farm, in the process the soils are trampled and bared, thereby, triggering soil degradation, but the devoured straws and leaves decay and add to the soil's organic matter and nutrient base.

5.4 Suggestions and Recommendations

The suggested solutions by the farmers include bush fallowing. This is largely recommended solutions for soil fertility decrease in these areas, especially with the availability of land and the current population level of the area. But this practice is

sure to diminish with increasing population growth that is accompanied with decrease in the number and sizes of farm plots due to tenancy by inheritance.

The use of fertilizer is a good practice that would readily increase the basic nutrient requirement of the plant in the area, particularly nitrogen rich fertilizers. But extra care must be borne in mind to reduce contamination, especially with the use of excess phosphorus. As heavy phosphate application reduce the availability of cationic metals but have the opposite effect on anionic compounds like arsenic. Therefore, care should be taken with phosphorus applications because high levels of phosphorus in the soil can result in water pollution.

The use of manure is also a strongly recommended practice following the importance of organic matter in soil. "Kushere" is another practice that should be looked into, understood and improved as it could help in nutrient cycling and maintaining organic matter level in the soil.

Planting of tress and grasses should be encouraged not only on Zuba dissected terrain but in all perceived areas vulnerable to erosion within the study area.

An integrated soil fertility management between the scientific and the traditional method should be encouraged through the work of extension services. This is important because some of the farmer's best practices prove highly desirable for fertility management.

And lastly, researchers are needed in the areas of soil fertility and soil fertility management to understand the status of soil fertility and farmer's management practices for a better soil conservation adaptation.

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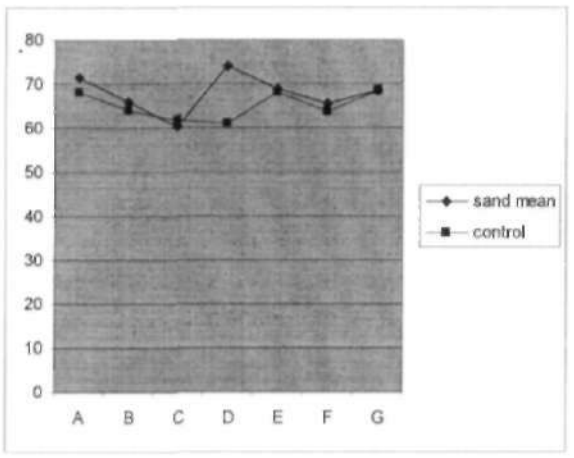
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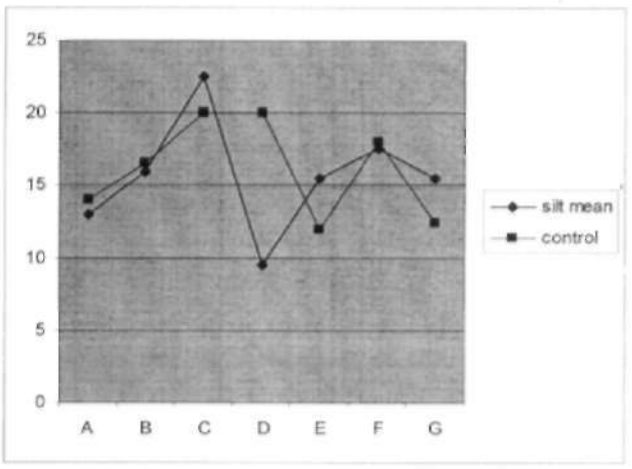
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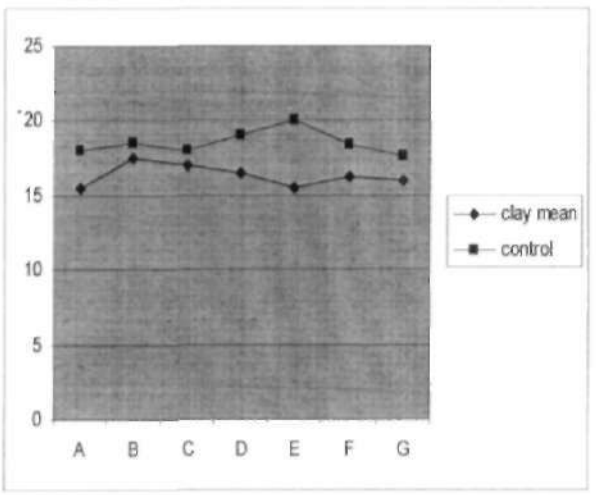
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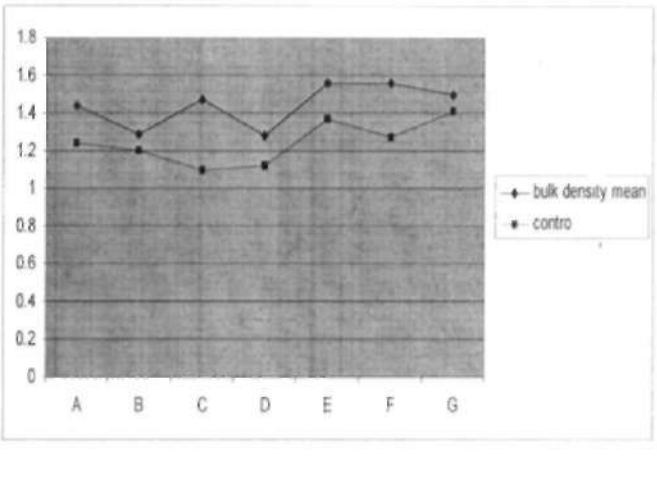
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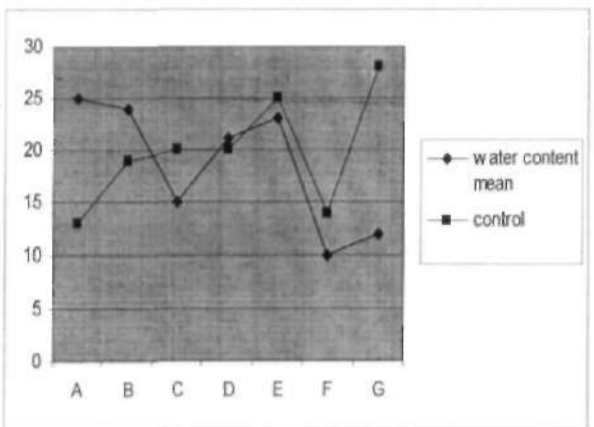
APENDIX A

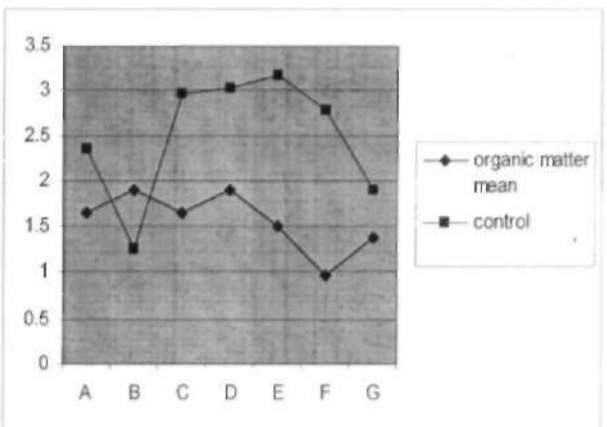

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50
40
30
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A B C D E F G
sand mean
control

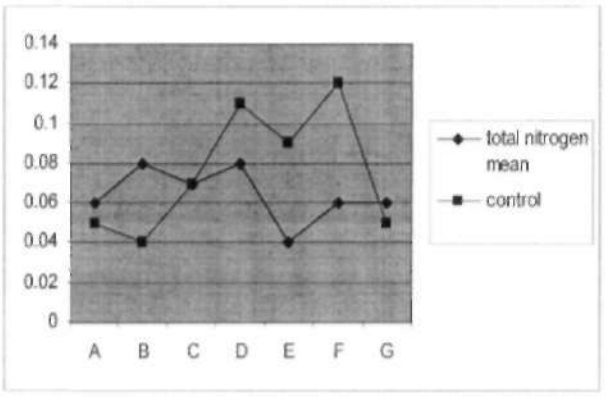

25
20
15
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silt mean
control

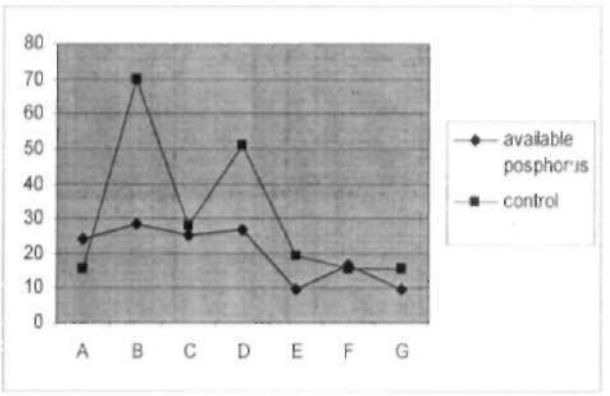

25
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clay mean
control

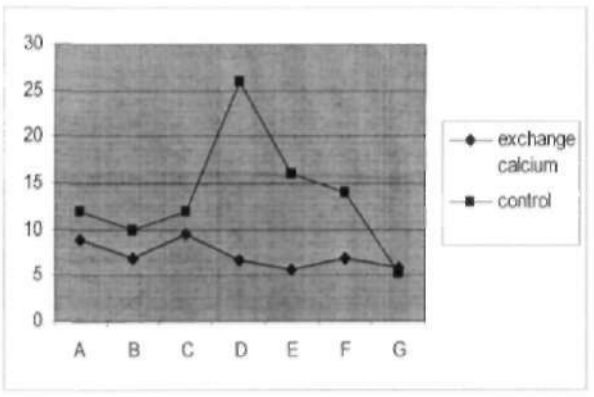

1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
A B C D E F G
bulk density mean
contro

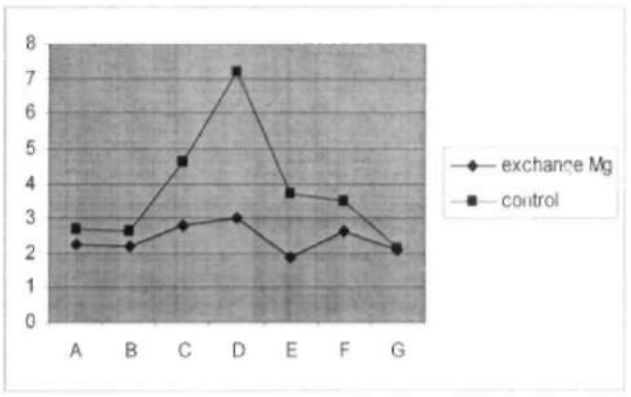

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20
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water content mean
control

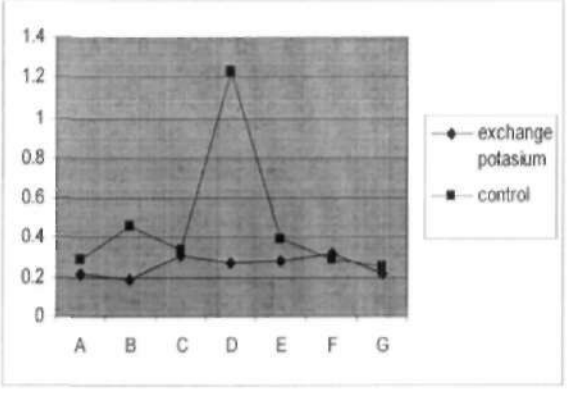

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3
2.5
2
1.5
1
0.5
0
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organic matter mean
control

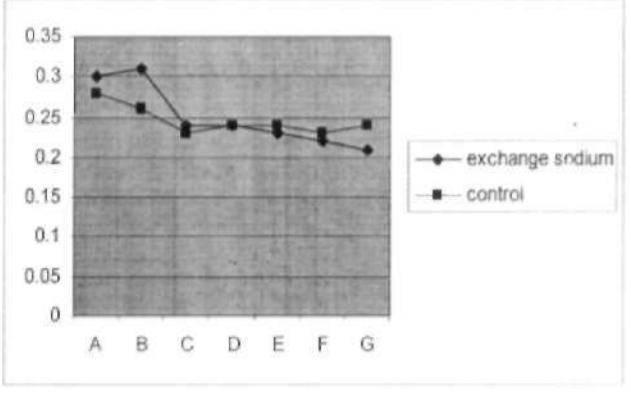

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0.12
0.1
0.08
0.06
0.04
0.02
0
A B C D E F G
total nitrogen mean
control

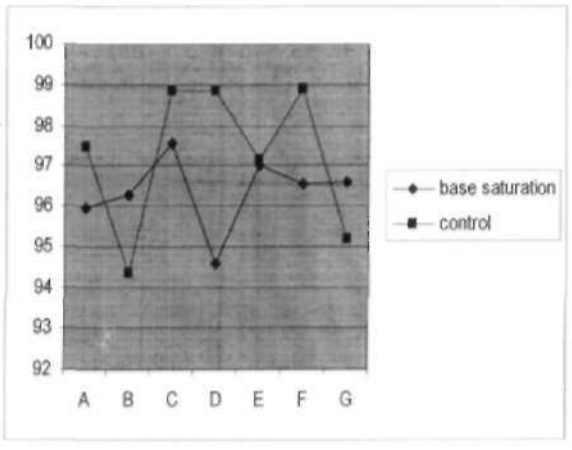

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0
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available posphorus
control

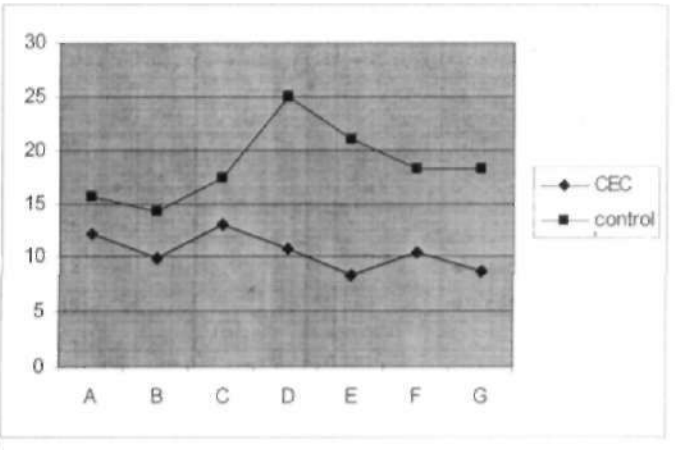

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15
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5
0
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exchange calcium
control

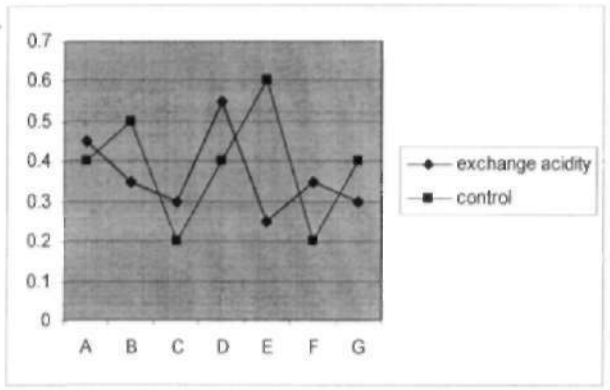

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A B C D E F G
exchance Mg
control

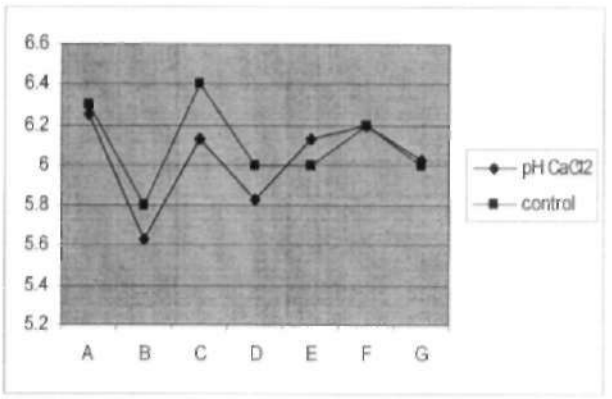

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0.4
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0
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control

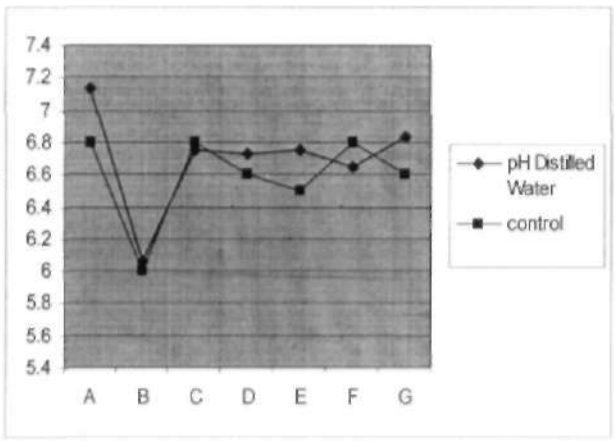

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0.25
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0.15
0.1
0.05
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exchange sodium
control

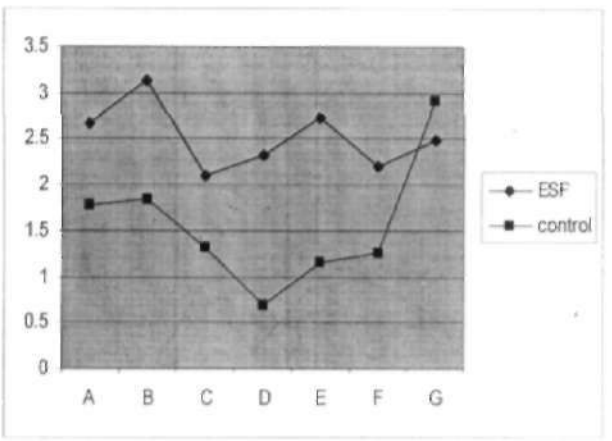

100
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92
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base saturation
control

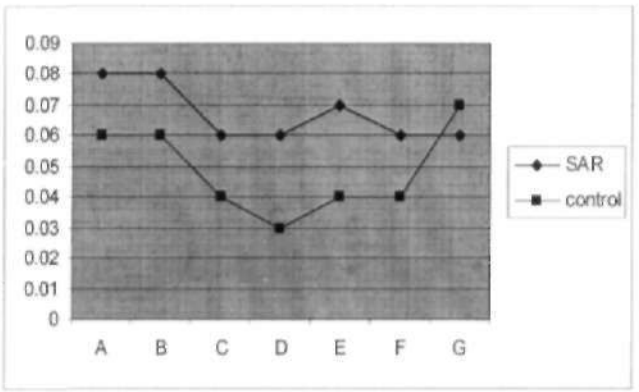

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control











Key;

A =Giri-Wuna, B= Giyabiri, C= Ledi, D= Dadabiri, E= Paikon kore, and F= Tungan Mallam Hassan

G= Gurfata

APPENDIX B

Department of Geography

Ahmadu Bello University,

Zaria, Kaduna State

Nigeria

QUESTIONNAIRE ON THE FARMER'S SOIL MANAGEMENT PRACTICES UNDER RAIN-FED AGRICULTURE IN GWAGWALADA.

1. Village name.....
2. State of origin.....
3. Age: (a) 21-25 [ ] (b) 26-30 [ ] (c) 31-35 [ ] (d) 36-40 [ ] (e) 41-above [ ]
4. Sex: (a) Male [ ] (b) Female [ ]
5. Marital status: (a) Single [ ] (b) Married [ ] (c) Divorce [ ] (d) Widow/Widower
6. Highest Education attained: (a) Informal education [ ] (b) Primary education [ ] (c) Post secondary education (d) Post secondary education [ ] (e) Other specify.....
7. Income Level (a) Less than N50,000.00 per annum [ ] (b) N50,000.00-N100,000.00 per annum [ ] (c) N101,000.00-N200,000.00 per annum [ ] (d) Above N200,000.00 per annum [ ]

SECTION B: LAND ACQUISITION AND AGRONOMIC PRACTICES

8. Main Occupation: (a) Farming [ ] (b) Civil Service [ ] (c) Fishing [ ] (d) Cattle rearing [ ] (e) Mining [ ] (f) Others.....

9. How many number of plots do you have……..

10. What are the sizes of your farms? (a) Less than 3 ha [ ] (b) 3-5 ha [ ] (c) 5-8 ha [ ] (d) 8 ha and above [ ]

11. What are the types of crops grown in your farm?

(a)…… (b)……..(c)…… (d)…… (e)……..(f)……..

12. What do you do with your crop residue?

(a) Burn them [ ] (b) Use them as feed [ ] (c) Use them for cooking [ ] (d) Others (specify)……

13. Do you use fire as part of your land management practices?

(a) Yes [ ] (b) No [ ]

14. Which of the following do you use fire for on your farm?

(a) Clearing of new land……..

(b) Cleaning of weeds……..

(c) Pasture re-growth……..

SECTION C: SOIL FERTILITY AND DEGRADATION PROBLEM

15. How do you assess soil fertility on your cultivated land?

(a) Increasing……(b) Decreasing……..(c) Unchanged……

16. If decreasing, what features made you to believe that such problem exist?

(a) Decrease in crop yield [ ] (b) Stunted growth of crops [ ] (c) Late growth and maturity of crops [ ]

(d) Presence of diseases [ ] (e) Others

(Specify).....

17. If increasing or decreasing, what are the major reason(s)?

(a).....

(b).....

(c).....

(d).....

18. Which of the following do you experience on your farm?

S/no	*Nature*	*Severity (mild, moderate, very)*	*Influencing factor e.g. ridging pattern, grazing, burning, continuous cultivation*
1	Compaction		
2	Loose surface		
3	Wind erosion		
4	Sheet erosion		
5	Rill erosion		
6	Gully erosion		
7	Structure less		
8	Deposition		
9			

SECTION D: SOIL CONSERVATION

19. Which of the following method do you apply on your farm (give reason for application of particular methods?)

S/no	*Conservation method*	*Reasons for application*
1	Mixed cropping	
2	Mono cropping	
3	Mixed farming	
4	Bush fallowing	
5	Crop rotation	
6	Mulching (state materials used)	
7	Chemical fertilizer application	
8	Organic manure (state type)	
9	Agro forestry (i.e. crops and tree together)	
10	Bush burning	
11	Ridging (state type and alignment)	
12		
13		
14		

20. How do you think soil fertility and degradation problem can be solved in your area?

(a).....

(b).....

(c).....

(e).....

(f).....

APPENDIX C: RATING FOR SOIL DATA INTERPRETATION

1. Soil Depth	
Very shallow	< 25cm
Shallow	25 – 50cm
Moderately deep	50 – 100cm
Deep	100 – 150cm
Very deep	> 150cm
2. Soil Reaction	
Extremely acid	<4.5
Very strongly acid	4.5 – 5.0
Strongly acid	5.1 -5.5
Moderately acid	5.6 – 6.0
Slightly acid	6.1 – 6.5
Neutral	6.6 – 7.3
Slightly alkaline	7.4 – 7.8
Moderately alkaline	7.9 – 8.4
Strongly alkaline	8.5 -9.0
Very strongly alkaline	> 9.0
3. Organic Carbon (%)	
Low	< 1%
Medium	1 – 1.5%
High	> 1.5%
4. Total Nitrogen (%)	
Low	< 0.15%

Medium		0.15 – 2.0%		
High		< 2.0%		
6. Exchangeable Cation(mol (+) Kg^{-1})	**Ca**	**Mg**	**K**	**Na**
	0 – 2	0- 0.3	0 – 0.15	0 – 0.1
Low	2 – 5	0.3-	0.15 – 0.3	0.1 – 0.3
Medium	> 5	1.0	> 0.3	> 0.3
high		> 1.0		
7 Cation Exchange Capacity (cmol(+)Kg^{-1})	**NH_4Oac**	**ECEC**		
Low	< 6	> 4		
Medium	6 – 12	4 – 10		
High	> 12	< 10		
8. Base Saturation (%)	**NH_4Oac**			
Low	< 50			
Medium	50 – 80			
High	> 80			
9. Electrical Conductivity (Ece) (dsm^{-1})				
None saline	< 4			
Saline	> 4			
10. Sodicity	**ESP**	**SAR**		
Low level sodicity	**(%)**	< 13		
High level sodicity	< 15	> 13		
	> 15			
11. Chloride ($MgKg^{-1}$)				

Low	< 2			
Moderate	2 – 8			
High	> 8			
12. Boron ($MgKg^{-1}$)				
Low	< 0.5			
Medium	0.5 – 2.5			
High	> 2.5			
13. Sulphate ($MgKg^{-1}$)				
Low	< 5			
High	> 5			
14. Micronutrients ($MgKg^{-1}$)	**Zn**	**Cu**	**Mn**	**Fe**
Low	< 1.0	< 0.2	< 1.0	< 4.5
Medium	1.0 – 2.0	0.2 – 1.0	1.0 – 5.0	-
High	> 2.0	> 1.0	>5.0	> 4.5

Source: Soil survey Staff, 1975